KRŌMSKŌP

COLOR PHOTOGRAPHY

BY

FREDERIC IVES.

WITH CHAPTERS ON

THE NATURE OF LIGHT AND THEORY OF COLOR.

BY SOME OF THE FIRST AUTHORITIES.

LONDON:
THE PHOTOCHROMOSCOPE SYNDICATE LIMITED,
121, Shaftesbury Avenue, W.C.

1898.

[A very rough suggestion of Kromskop images, first viewed separately, and then optically superposed to form a single image in the natural colors.]

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INDEX.

Part Two.

THE KRŌMSKŌP.

THE KRŌMSKŌP is an optical instrument which accomplishes for light and color what the Phonograph accomplishes for sound and the Kinetoscope for motion. Although it does not produce fixed colored photographs, it is a veritable realization of color photography to the extent of bringing before the eyes, by a simple and practical process, a photographic image in the natural colors which is far more perfect and realistic than any colored picture on paper could possibly be, because it is perfectly free from surface texture and reflections, and is seen without distracting surroundings, and in solid relief, exactly as the object itself is seen by the eyes.

The Krōmskōp system of color photography is based upon the fact that all the varied hues in nature are physiologically equivalent to mixtures of three simple spectrum colors, red, green, and blue-violet. The Krōmskōp photograph consists of three stereoscopic pairs of images, similar in appearance to ordinary uncolored lantern slides, but which, by differences in their light and shade, represent the distribution and proportions of the respective "primary" colors in the object photographed. The Krōmskōp photograph is therefore, although not a color photograph, a *color record*, just as the cylinder of the phonograph, although not a cylinder of sound, contains a record of sounds,

and the kinetoscope ribbon, although not an animated photograph, contains a record of motion. The phonograph cylinder must be placed in the phonograph before it can be made to reproduce the sounds recorded; the kinetoscope ribbon must pass through the kinetoscope in order to visually reproduce the moving scene; and the Kromogram must be placed in the Krōmskōp in order to visually reproduce the object photographed.

The Krōmskōp color record, unlike most colored pictures, is absolutely permanent, the same to day and fifty or even hundreds of years hence, and it is only necessary, in order to reproduce the colors which it represents, to illuminate the uncolored photographs, each by its appropriate colored light, and to optically superpose and blend them together, so that they are seen as a single image. This is accomplished in the Krōmskōp so perfectly that all suggestion of photography vanishes, and the very object photographed, be it flowers, fruit, portrait, landscape, or work of art, appears to stand before the eyes.

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CONSTRUCTION AND OPERATION OF THE KRŌMSKŌP.

The construction of the Krōmskōp will be readily comprehended by studying the sectional plan beneath.

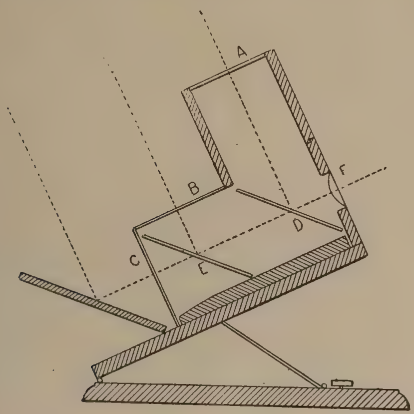


FIG. I.

A, *B*, and *C* are red, blue and green glasses, against which the corresponding images of the color record are placed when the instrument is in use. *D* and *E* are transparent reflectors of colored glass. *F* represents the eye lenses for magnifying the image. Beyond *C* is a reflector for illuminating the images at *C*—those at *A* and *B* being illuminated by direct light from above.

The operation of the Krōmskōp is as follows :—The green images are seen directly, in their position at *C*, through the transparent glasses *D* and *E*. The blue images are seen by reflection from the surface of the glass *E*, which makes them appear to occupy the same position, and in fact to become part of the images at *C*. In the same way the red images are seen by reflection from the surface of the glass *D*, and also appear to form part of the images at *C*. And finally, the eye-lenses at *F* not only magnify, but cause the eyes to blend the two images which constitute the complete stereoscopic pair, as in the ordinary stereoscope. The result is a single image, in solid relief, and in the natural colors.

When there is no Kromogram in the instrument, the mixture of the three pure colors produces white. Shading either of the glasses produces color, and it is the function of the Kromogram, by the varying density of its images, to make such a mixture of the pure colors as will reproduce all the infinite variety of light and shade and color of the objects photographed.

The Krōmoskōp negative is made on a single photographic plate, at one exposure in a special camera, by which the records of color are obtained automatically and accurately. The positive record is made by contact-printing from the negative, in the usual way; the glass plate is then cut in three and mounted on the special hinged frame, designed to bring the respective pairs of images readily into position in the Krōmskōp. The Kromogram, thus formed, can be changed with great facility and quickly folded up for putting away.

INSTRUCTIONS FOR USING THE KROMSKŌP.

[To obtain the best results with the Krōmskōp, the following instructions must be carefully followed. Careless handling would only result in disappointment ; but attention paid to the instructions should enable even a child to handle the instrument successfully. It will be found a good plan to keep the Krōmskōp under lock and key, and in the charge of one individual, who will take pride in exhibiting it properly, and keeping it in perfect order.]

When using the Krōmskōp by day it should be placed close to a window, so that the light from the sky may fall directly upon it, without the interference of sash bars, blind-cords or other obstructions. It must be remembered that the actual colors of the original object are only seen when all three sections of the triple Kromogram are evenly and equally illuminated. Where walls or other objects opposite the window prevent the access of light direct from the sky to the instrument, the colors will not be truly reproduced. But where direct light from the sky cannot be had, recourse may be had to the Krōmskōp Lamp, which has been designed especially for evening illumination.

When the Krōmskōp has been placed on a small table near a window facing a sufficient expanse of sky, the external mirror (the position of which is regulated by a screw) should be released. The body of the instrument should then be inclined towards the light until an even field of nearly white light is seen through the

lenses, in which position it may be secured firmly by the screw which travels in the slot beneath.

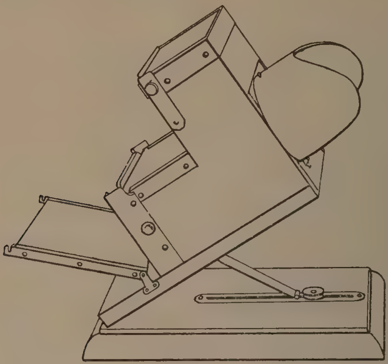


FIG. 2.

If there is a sufficient expanse of even white or grey sky the field will appear evenly illuminated, and nearly, if not quite, white. If slightly pink or green rather than white, a slight alteration of the angle of the external mirror, or of the inclination of the Krōmskōp, or both, will readily correct this. Do not insert a Kromogram until the field is even and white, as under no other conditions will the different sections of the Kromogram be equally illuminated.

If, when the field is even and sufficiently white, there is a line of red at the top and green at the bottom, the block carrying the colored glass reflectors has become displaced; open the door carrying the hood and eye lenses, and press the block in against the stop, which is underneath the block, on the right side, in line with the projecting screw. A steel wire spring,

underneath, holds this block down and against the right side of the box, but it requires to be pressed into place against the stop, to secure true register.

With a blue sky, the field will at its best appear blue tinted, but the eye will soon accommodate itself to this, so that the colors will appear as good as they would be under some conditions of daylight illumination of the object. On the other hand, there is a condition of blue sky illumination which gives a field that is distinctly *green* instead of blue. This is when the Krōmskōp is directed to a part of the sky which is at about 90 degs. to the right or to the left of the position of the sun. The light of the sky in that position is considerably polarised, and the Krōmskōp colored glass mirrors under the red and blue images do not so freely reflect such polarised sky light. Since the foregoing statement was put in type, the writer has succeeded in nearly eliminating this defect, by alterations which include the substitution of a series of clear glass reflectors for the outside silvered mirror, so that the conditions as to reflection of polarised light are nearly the same for all images.

If the sky is uneven, or made up of white and blue in patches, or interrupted by branches or foliage, or other objects, the Ground-glass Screen must be used, as shown at A in fig. 3; but even when this is used, it is necessary to correctly adjust the inclination of the instrument and the external mirror to get an even white field. The Ground-glass Screen is readily attached to the front edge of the external mirror, and when thus placed must be leaned forward out of the way when changing a

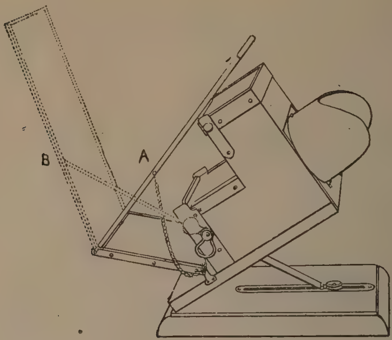


FIG 3.

Kromogram, and inclined back over the instrument and resting upon it, when viewing one. The chain and loop enable the screen to be secured when leaned forward, as shown at B in the Fig. 3.

In all cases, avoid letting the direct rays of the sun come into the Krōmskōp.

When the Krōmskōp is set to give an even white field of light to persons having normal color vision, about one male in twenty, and a smaller percentage of females, will see it more or less blue-green, owing to partial red color-blindness; and this will be true even though the color-blindness may not be sufficient to have been discovered under ordinary circumstances, the mixture of spectrum red, green, and blue in the Krōmskōp forming a most sensitive test. To a partially green color blind person, the same field will appear pink or magenta tinted; but green color blindness is very rare.

HANDLING THE KROMOGRAM.

It is of the first importance that the Kromogram should always be placed correctly in the Krōmskōp. If placed upside-down, or reversed, the result would be confusion; but the following instructions if followed will make the changing of the Kromogram the simplest thing.

It should always be folded so that the small round numbered label comes at the top, and on the right hand side, as seen in fig. 4. It is picked up by taking hold of the top section

FIG. 4.

with the thumb and two fingers of the right hand, the first finger over the small label. This brings the *name label* on the blank section in front of the eyes, as in fig. 5.

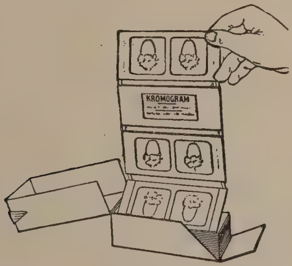


FIG. 5.

The lower section may now be taken by the left-hand edge, with the thumb and finger of the left hand, and lowered into its grooves at the front of the lower step of the Krōmskōp, as shown in fig. 6, the second section is then allowed to fall upon the top of the lower step, *taking care to lift it over the upwardly projecting*

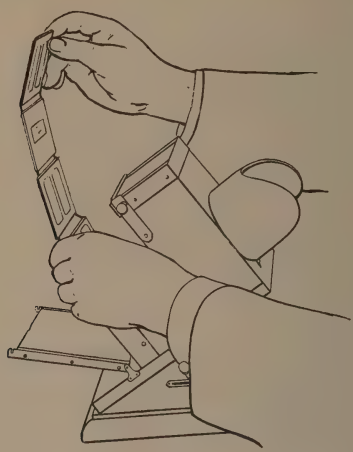


FIG. 6.

glass, which serves as a stop for it when it falls into place and then the top section may be similarly placed on the top step. It is then necessary to push each section (including the green) from the right hand side against the stops on the left of the steps, in order to bring the images into superposition, so that they appear as one well-defined correctly-colored image, when viewed from the eye lenses.

In viewing the Kromograms in the KRŌMSKŌP, *the eyes should be brought centrally over the lenses, so that the image appears symmetrically disposed within the circle of sight.*

The Kromogram may be lifted out of the Krōmskōp by one hand only, and may be quickly folded up by lowering it upon the table, or upon the palm of the left hand, with a to-and-fro motion, which brings the round number-label at the top.

If the Kromogram is *always* folded with the round number-label outside, and *always* picked up and inserted in the Krōmskōp as directed, habit will soon make it natural and easy to change them quickly without making mistakes, and without injury to the Kromogram or its mounting. They should never be folded in any way but that indicated, and should never be put in the box wrong side up.

INSTRUCTIONS FOR USE IN THE EVENING.

When using the Krōmskōp at night or in an insufficiently lighted room, the Krōmskōp Lamp supplies a good even illumination. The Welsbach Incandescent Gas light is employed, and this, when modified by the combination of tinted and opal glass, and aided by the internal reflectors, gives a light which is apparently quite white when compared with ordinary gaslight; but in reality it is not quite so white as daylight, and although very satisfactory for most subjects, will not do full justice to landscape Kromograms.

The manner of using the Krōmskōp Lamp is best shown by reference to fig. 7. The Krōmskōp is pushed against a stop provided for it upon the extending base of the lamp, and is inclined forward as far as possible. The hanging mirror of the Lamp is allowed to rest upon the top of the instrument, and the

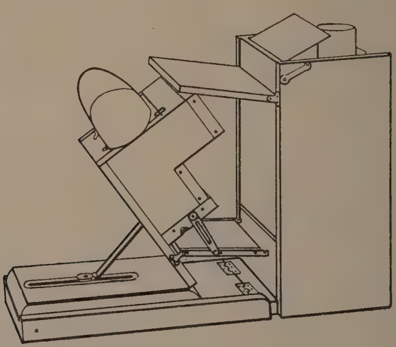


FIG. 7

external Krōmskōp mirror must then be very carefully set at the exact angle necessary to secure as even and white a field as possible. The Lamp mirror turns back to permit of changing the Kromograms, but must always be replaced before viewing them. The pressure of gas in the Welsbach lamp must be carefully regulated to give the best light. If the Welsbach mantle is not filled with incandesence, the gas pressure is not right for the burner, and if it is insufficient, the burner can be readjusted by any agent of the Welsbach Company.

CARE OF THE KRŌMSKŌP.

Under the ordinary circumstances, the Krōmskōp requires only to be kept clean and free from dust in order to operate satisfactorily. Every finger-mark or dust-speck on the glasses, either of the Krōmskōp or Kromogram, is apt to show as a spot or speck of color. The reflecting mirror, the outside colored glasses, and the eye-lenses, may be wiped off with a silk or soft linen handkerchief, and dusted with a camel's hair brush. The small door carrying the eye-lenses may be opened to clean or dust them.

When the colored glass reflectors require dusting, the wooden slide to which they are attached should be carefully drawn out, and all parts of the inside of the instrument can then be dusted.

If the colored glass reflectors require wiping, as is likely to be the case about once a month, they should be removed for

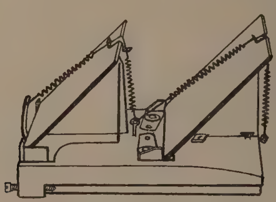


FIG. 8.

that purpose, by unhooking the springs which hold them in

place. In putting the reflectors back, after cleaning them, see that the corner with an X scratched upon it comes next to a similar mark on the wooden base—otherwise the instrument will be out of register. These colored glass reflectors are of specially manufactured glass, optically worked, and are more expensive to replace than any other part of the instrument. If broken, they can only be replaced, and the instrument re-adjusted, at the manufactory of the PHOTOCHROMOSCOPE SYNDICATE

ADJUSTMENT OF THE KRŌMSKŌP.

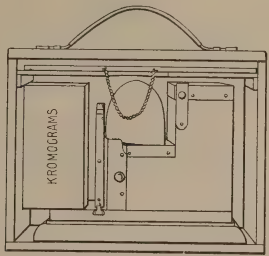
Each instrument is very carefully adjusted before being sent out, so that when the sections of the Kromogram are pushed against the stops the different colored images are perfectly superposed. The effect of imperfect adjustment may be seen experimentally by pushing one of the sections away from its stop, a movement of a hundredth part of an inch being sufficient to show fringes of false color on the edges of objects. Should such fringes of color appear when the Kromogram sections are all in their correct positions against the stops, and the block carrying the colored glass reflectors pressed in against its stops, a slight re-adjustment of the instrument is required, and two adjusting screws are provided for this purpose. A slight turn of the screw on the left side, which adjusts the stop for the red picture at the top of the instrument (keeping the Kromogram *gently* pressed against it while turning), will remove color fringes *at the sides* of objects, and a similar movement of the screw which projects through an opening at the bottom of the right hand side of the door carrying the eye-lenses will remove color fringes at the top or bottom of objects. This screw requires to be turned with a small screw-driver, but seldom needs attention. Considerable change of temperature, or a spell of very damp or very dry weather, have been found sometimes to affect the register sufficiently to permit of improvement by a slight turn of this screw.

A Kromogram may fail to register even when the instrument

is in perfect order if the edges of the mount have been bruised by careless handling; but when the Krōmskōp is in perfect register for one unmutilated Kromogram, it will be in register for all others.

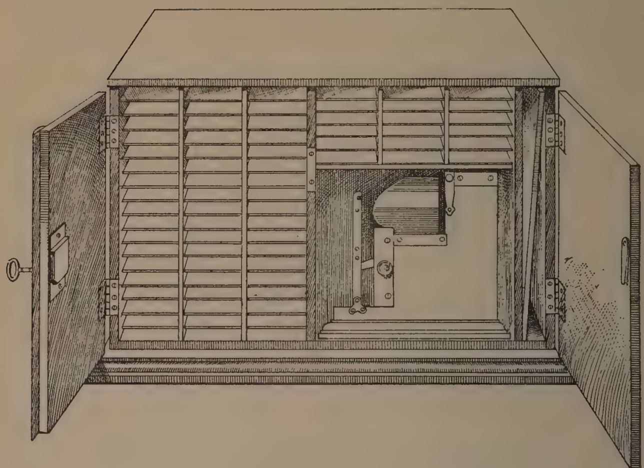
The glass side of the Kromogram is readily cleaned by rubbing with a soft linen handkerchief, but the picture side, which is protected by the mount, cannot be rubbed without scratching, and should never be touched by the fingers.

Both the Krōmskōp and the Kromograms should be handled with the same care that would be given to a fine microscope or other delicate optical instrument, and kept in a dry place at an equable temperature.



THE KRŌMSKŌP,

IN ITS CARRYING CASE (DOOR REMOVED).



KRŌMSKŌP CABINET.

THE JUNIOR KRŌMSKŌP.

The Junior Krōmskōp is a monocular (non-stereoscopic) instrument, with a focussing eyepiece. The Kromogram consists of three images only, which are somewhat larger than those of the stereöscopic Kromograms.

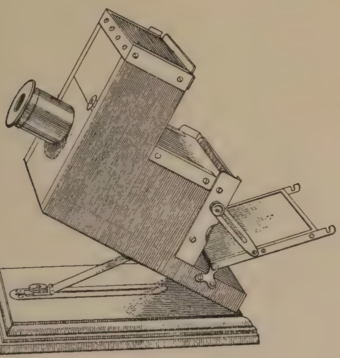


FIG. 9.

Both the instrument and the Kromograms are cheaper than the other form, but are equally perfect and satisfactory for the reproduction of paintings and other flat surfaces, and this form of instrument and Kromogram will sometimes be preferred,—by artists who are accustomed to see everything mentally as a picture

instead of a solid object, by amateur photographers who wish with the least trouble and expense to make their own Kromograms, and by anybody to whom the difference in price is of importance.

The construction and operation of this instrument are so similar to that of the stereoscopic Krōmskōp that the same instructions will apply.

THE LANTERN KRŌMSKŌP.

The Lantern Krōmskōp is an optical device for attaching to an ordinary electric or limelight lantern for the projection of Krōmskōp color photographs upon a screen, so that they can be seen by a large number of people at once.

It is necessary to remove the ordinary optical front in order to employ this attachment, as only a small condensing lens is used, to give parallel rays, which are divided by means of transparent reflectors, and made to pass through the respective colored glasses and images of a specially-mounted Kromogram and separate objectives.

Two of the objective carriers are pivoted near the Kromogram stage, so that, by means of a lever, they can be swung aside, showing the separate colored images side by side upon the screen, and then, by reversing the motion of the lever, superposing them in exact register. This method of projecting the pictures is very effective, not only as a means of demonstrating the principles of Krōmskōp color photography, but because the sudden appearance of a perfect color photograph out of a jumble of crude colors affords a fresh surprise and delight with each subject.

The construction of the Lantern Krōmskōp is shown by the diagram, Fig. 10, in which *g* is the small condenser, giving a beam of parallel rays, and *h*, *i* are bundles of clear glass which serve to divide the beam into three. The light incident on the first bundle, *h*, is partly reflected to a silvered mirror *k*, from

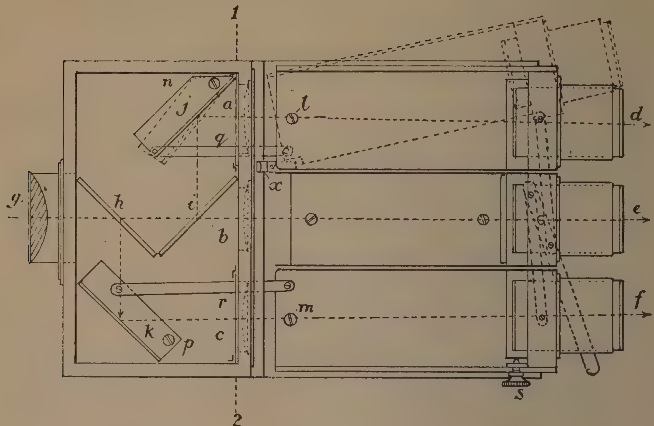


FIG. 10.

which it passes through the red color screen, and the image of the red sensation, at *c*, to the objective *f*, and thence to the screen. Two-thirds of the light passes through the bundle of glass, *h*, and this is again divided by a thicker bundle, *i*, about half of it going to the silvered reflector *j*, and thence through the blue screen and image of the blue sensation to the objective, *d*, and thence to the screen. The portion of light which passes through both of the bundles of glass goes through the image of the green sensation, and thence through a green glass and the objective *e*, to the screen.

The objectives are so adjusted that the three axial rays converge to one point upon the screen when the lever system is closed, but separate widely when it is opened, the coned beam of light being kept in the axis of the moving lenses by the

operation of the levers q and r, which connect the pivoted objective mounts of the respective silvered mirrors.

Although the Lantern Krōmskōp can be used with any lantern by removing the ordinary optical front, it is especially adapted for use with a "Popular Science" lantern devised by the author. This lantern is shown in Fig. 11., as used for

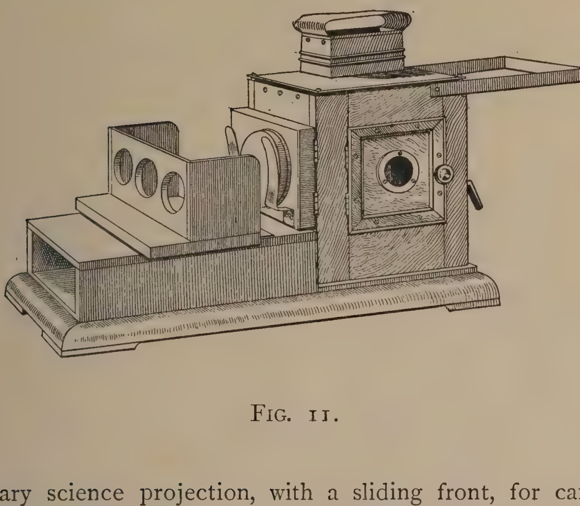


FIG. 11.

ordinary science projection, with a sliding front, for carrying three projection systems (such as ordinary objective, microscope or micro-polariscope, and direct-vision spectroscope), and making instantaneous changes by moving it to stops. This multiple front can be lifted off, and the condenser mount and slide carrier swung to one side, leaving a clear platform which supports and centers the Lantern Krōmskōp, as shown in Fig. 12.

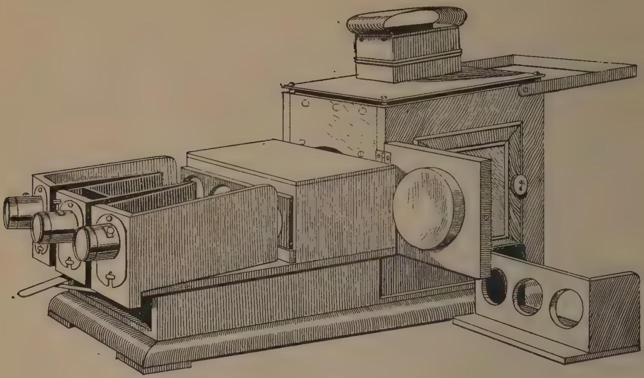


FIG. 12.

It is then necessary to push the lamp or jet towards the condenser until the disk on the screen is filled with light. Careful centering and adjustment is necessary to obtain an evenly illuminated disk, which can be separated by the movement of the lever into three colored disks, which are also evenly illuminated.

The register is adjusted by putting in a slide, closing up the lever so that the objective carriers come together, focussing carefully by sliding the objective barrels in their tube mounts, and then shifting the mounts carefully until the details of the pictures are in perfect register. If the lens mounts will not shift far enough to bring the images into register, the objective barrels can be revolved in the tubes until a position is found which permits of register with less shifting of the mounts. If either one of the images is too large or too small, the size can be made

right by a slight readjustment of the focus of that particular objective. Whenever the lenses are taken out to clean, it will probably be found that readjustment is necessary, owing to the imperfect centering of such lenses.

The objective for the blue image is shifted by loosening the set screw, and moving by hand. That for the red image has a fine adjustment by screws acting at the top and side.

It is, of course, impossible to make satisfactory projections of more than four feet in diameter with the limelight, after dividing it into three portions and filtering through three color screens; but the results are very effective even in small sizes upon a screen used for much larger projections of ordinary slides. With the electric arc (direct current), excellent results can be obtained up to 10 feet in diameter, *on an opaque screen.* A single linen screen is unsuitable.

When using the limelight, the lime must be turned so as to prevent pitting, sufficient to shoot the flame forward towards the condensing lens, which is of much shorter focus than the ordinary lantern condensers. Several condensers have been broken by not taking this precaution, but none have yet been broken by the heat of even the most powerful electric arc that can be used in the lantern.

For limelight color projections on a larger scale, the author has devised a compact triple lantern with three jets, which can be made to order.

THE KRŌMSKŌP CAMERAS.

In order to make the successful production of Krōmskōp negatives as simple and certain as ordinary monochrome photography, it is necessary to make the three images which constitute the color record (identical in size and perspective) upon a single sensitive plate, by simultaneous exposure, from one point of view. This can only be accomplished by the use of one of the author's patented cameras. In the original camera, patented in 1892, the images are arranged in trefoil upon the glass plate; but in the camera devised especially to make negatives for the Krōmskōp, they are so arranged as to fill an oblong plate, the centers being on a line.

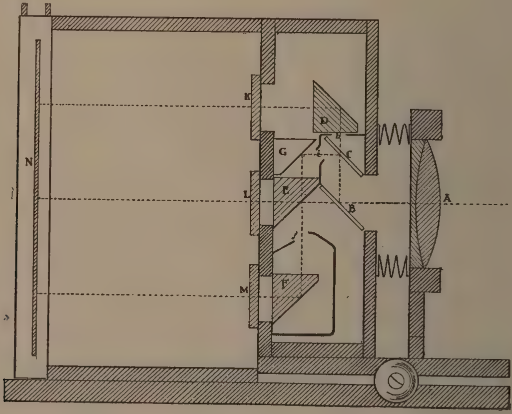


FIG. 13.

The construction of this camera is shown by the sectional plan, Fig. 13. A is a single achromatic lens; B and C are transparent reflectors (of colored or thinly-silvered glass); D, E, F, are rectangular prisms, silvered on the reflecting surfaces; G is a silvered glass reflector; K, L, M, are color screens; N is the sensitive plate; *h*, *i*, *j*, are diaphragms to regulate the amount of light going to the respective images.

The axial light ray from the object, after passing through the lens A, is partly reflected and partly transmitted by the transparent mirror B. The portion that is transmitted is reflected from the silvered surface of the prism E, downwards through the diaphragm aperture *j*, into the rectangular prism F, and from thence by reflection through the color screen M, to the lower section of the sensitive plate, where one of the images is formed. The light which is reflected from the transparent mirror B, is again divided by the transparent mirror C. The portion that is transmitted passes upward through the diaphragm aperture *h*, into the rectangular prism D, and thence by reflection through the color screen K, to the upper section of the plate, where another image is formed, identical in size and perspective with that on the lower section. The portion of light which is reflected from the second transparent mirror (C) passes through the diaphragm aperture *i*, to the silvered mirror G, downwards into the prism E, and thence by reflection through the color screen L to the middle section of the sensitive plate. The bending of this ray from B to C and G to E makes it of the same length as the rays going to the outer section of the plate, so that the middle image is identical in size and perspective with the others.

About three-quarters of all of the light goes to the lower image, which is made to represent the fundamental color to which the plate is least sensitive. By this means, the diaphragm apertures do not differ greatly in size for the different images when the selective color screens are adjusted for a particular plate, and slight variations in different batches of emulsion are sufficiently compensated for by small changes in the relative size of the diaphragm apertures.

This form of camera, as adjusted for making negatives for the Junior Krōmskōp and the Lantern Krōmskōp, is comparatively simple, and in careful hands should not get out of order. The external appearance is shown in Fig. 14. The front, carrying the focussing lens and covering the internal optical system can be opened to clean the mirrors and prisms ; *but the silvered sur-*

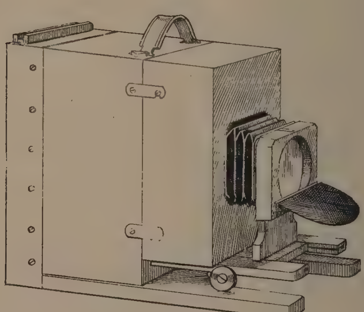


FIG. 14.

faces G *and* E *can only be dusted, with a soft camel's hair brush.* The transparent mirror B is mounted to swing out of the way and transmit the greater part of the light to the lower section, for convenience in composing and focussing the image. *It must of course be replaced before drawing the slide to make an exposure.*

Negatives made with this camera contain only three images, and are therefore not stereoscopic; but if wanted to make Kromograms for the stereo-Krōmskōp, it is only necessary to make the positives in a suitable duplicating camera, so that there are three pairs of images, which fits the stereoscopic mounts, and show perfectly in the stereo-Krōmskop, although without stereoscopic relief.

By making the Krōmskōp camera to take a wider plate, and attaching a pair of mirrors in front (Brown's stereoscopic transmitter), it is adapted for the production of stereoscopic Kromogram negatives. All of the landscape Kromograms sold for use in the stereo-Krōmskōp are from negatives that were made with this form of the camera.

With the Krōmskōp camera it is necessary to give exposures of one minute and upwards on well lighted landscapes, and proportionately longer in the studio. It is therefore not adapted to reproduce objects that cannot be depended upon to keep their position for some time. For quick work in the studio it is necessary to employ either a special camera that makes the color record on separate plates at one exposure, or one that makes the three images by successive exposures on one plate. The author has devised an automatic camera, Fig. 15, operated by a

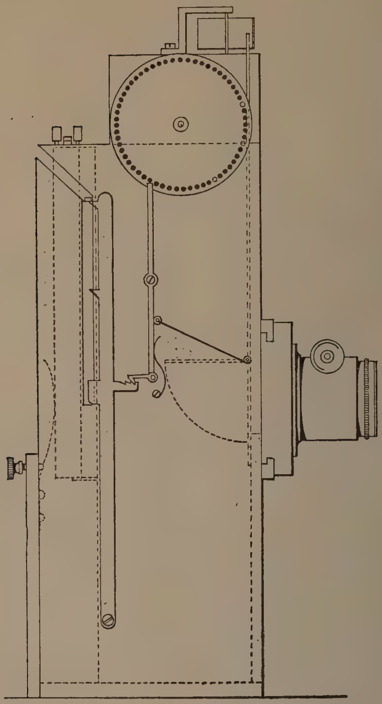


FIG. 15.

small spring motor, which makes the three exposures, on one plate, in rapid succession, and in any desired relative proportion to each other, so that the three exposures together may occupy

from fifteen seconds up to three minutes, as desired. A full description of this camera appears in the British patent No. 3232, 1897.*

Both of the cameras described are necessarily expensive, and the author has therefore produced, for amateur and experimental Krōmskōp photography, a comparatively simple and cheap multiple back, with sliding dark slide and color screens to fit any ordinary quarter or half-plate camera, and make the negatives by successive exposures on one plate. This attachment affords a means of making perfect negatives for the Junior and Lantern Krōmskōps, provided that the object keeps its position, and the relative exposures are given correctly, in an unchanging light. In a changing light, *accurate* results are so uncertain as to soon make evident to the operator the value and importance of the more elaborate and expensive Krōmskōp camera; but there will always be found some subjects for which this attachment possesses advantages, because it can be used with lenses of any focus or aperature, and with the microscope and polariscope,and for the photography of small objects generally by a steady artificial illuminant, such as the Welsbach light.

The Junior Krōmskōp and this multiple back, form a complete but inexpensive outfit for readily reproducing a great variety of objects in their natural colors as perfectly as it is possible to do it with the more expensive forms of apparatus.

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* Complete Specification filed November, 8th.

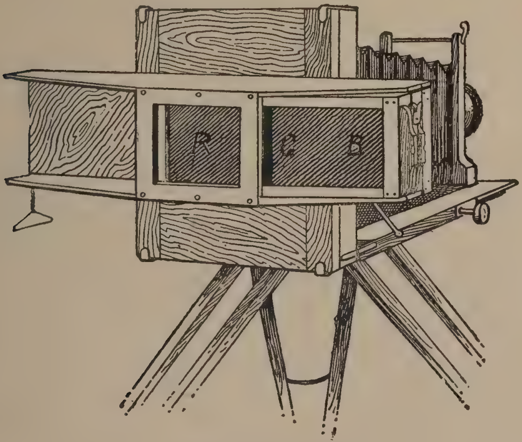
KRŌMSKŌP PHOTOGRAPHY.

It is absolutely necessary to use in any of the Krōmskōp cameras the kind of ortho-chromatic sensitive plates for which that particular camera has been adjusted; and the relative size of the diaphragms, or in the case of the automatic camera or simple multiple back, the relative time of exposure must be such as to give images of uncolored objects which are identical in density and gradations, with the particular source of light employed, preference being given to direct or diffused sunlight. If these conditions are not adhered to, the coloration of the reproductions will necessarily be incorrect. It is true that a skilful operator may sometimes slightly intensify an under-exposed image, or reduce an over-exposed one, after the negative is made; but the result can never be quite as good as when the relative exposures are correct.

Metol is the best developer that the author has tried for these negatives. Hydroquinone is especially unsuitable with some plates, because with it one of the images lags behind in development, and equal density will not be secured in the three images unless the development is carried to just the right point. Even the metol developer should be freshly made up in order to avoid such a tendency. *The negatives must be soft and full of gradation, without being over-exposed.* Over-exposure has the effect of bleaching out the color of objects, and under-exposure exaggerates color contrasts. Too great density in the negatives

or under-exposure of the positives has a similar effect. Soft and even lighting is to be preferred, and violent contrasts of light and shadow must be avoided.

The positives may be made by contact printing in the dark room, by gas or lamp-light, on Cadett or Mawson & Swan photo-mechanical plates. The source of light should be at a sufficient distance to give equal illumination over the whole negative. Even with the most perfect negatives careful attention must be paid to the exposure and density of the positives, and it is recommended to send the negatives to the Photochromoscope Syndicate to have the positives made and mounted. The special mounts will, however, be supplied to those who prefer to do this work for themselves.



Multiple Back

THE PERFECTED PHOTOCHROMOSCOPE AND ITS COLOR PHOTOGRAPHS.

By Frederic Ives.

(Lecture before the Society of Arts, April 22nd, 1896).

For nearly fifty years the world has been hoping and looking for a direct process of photography in colors, and from time to time results have been obtained which led many people to think that the solution of this problem was near at hand. But in nearly every case it has proved that the colors obtained were either unlike or not dependent upon the color of the light rays which acted in their production, and it is an open question whether any real progress has been made towards realising a true and practical solution of the problem. Lippmann, by his interferential method, has certainly produced some very striking and even beautiful results, but in the course of several years only a few good examples have been produced by this method, in the hands of scientific experts, and nearly everybody has abandoned experiment with it in despair. The only practical success in the reproduction of colors through photography has been accomplished by an indirect process, which is best represented by the photochromoscope system, which I have been invited to demonstrate to you to-night.

The photochromoscope is an optical instrument, which by

the aid of the photographic process, accomplishes for light and color what the phonograph accomplishes for sound, and the kinetoscope for motion; but the necessary apparatus is comparatively simple and cheap, and the results are far more perfect. Based upon the trichromatic theory of vision, the photochromoscope system is a method of composite color photography, by means of three uncolored photographic images which constitute a color record, and synthesis by optical superposition of the three images, each illuminated by its appropriate colored light.

The first suggestion of such a method appears to have been made by James Clerk Maxwell, in a lecture delivered at the Royal Institution, London, May 17th, 1861. From the report of his lecture, which appeared in the proceedings of the Royal Institution, I quote as follows .—

"Experiments on the prismatic spectrum, show that all the colors of the spectrum, and all the colors in nature, are equivalent to mixtures of three colors of the spectrum itself, namely, red, green near the line E), and blue (near the line G).

"The speaker assuming red, green, and blue, as primary colors, then exhibited them on a screen by means of three magic-lanterns, before which were three glass troughs containing respectively, sulpho-cyanide of iron, chloride of copper, and ammoniated copper.

"A triangle was thus illuminated, so that the pure colors appeared at its angles, while the rest of the triangle contained the various mixtures of the colors, as in Young's triangle of color.

"The graduated intensity of the primary colors in different parts of the spectrum was exhibited by the colored images, which, when superposed on the screen, gave an artificial representation of the spectrum.

"Three photographs of a colored ribbon taken through the three colored solutions respectively, were introduced into the lantern giving images

representing the red, the green, and the blue parts separately, as they would be seen by Young's three sets of nerves separately. When these were superposed, a colored image was seen which, if the red and green images had been as fully photographed as the blue, would have been a truly-colored image of the ribbon. By finding photographic materials more sensitive to the less refrangible rays, the representation of the colors of objects might be greatly improved."

In the course of the quarter century following Maxwell's lecture, means for producing color-sensitive photographic plates were discovered and such plates were employed in the manner suggested by Maxwell, although his lecture appears to have been entirely forgotten, and the idea was for some years credited to Frenchmen, Ducos du Hauron and Charles Cros (1868), afterwards traced back to Henry Collen, an Englishman, and Baron Ransonnet, an Austrian, whose suggestions appeared in 1865; and only traced back to Maxwell 33 years after he delivered his lecture upon the subject at the Royal Institution.

There was a vital defect in all of the suggestions which had been recorded up to 1888, when I pointed out that, although pure colors must be used for synthesis, the color-filters through which the photographs are made must bear such a relation to the color-sensitiveness of the photographic plates as will secure, in negatives of the spectrum itself, density curves corresponding to the distribution of the respective color element in mixtures reproducing the spectrum. In other words, that while the color filters for synthesis must transmit only red, green, and blue-violet rays respectively, the color filters for the photographic process must, collectively, transmit all of the visible spectrum rays, and each must bear such a relation to the character of the sensitive plate as will secure photographic action corresponding to the

color-mixture curve. This might be said to amount to the formulation of a new principle, since, according to the report of Maxwell's lecture, to which I have referred, his photographic negatives were made through the same color-filters that he placed in front of the lantern objectives in making the color-mixture experiments, as was also afterwards done by Du Hauron, Lippmann,* and others. The theoretical and practical importance of the distinction which I have pointed out will be made clear by a sufficient examination into the science of the subject.

I shall be better able to show the nature and limitations of the means by which the reproduction of color is accomplished in the photochromoscope system, as well as the reasons for such definite modifications of the original procedure as I have already mentioned, if I may be permitted to commence with a brief consideration of the relations of light and color to the photographic process.

The wave motion which constitutes a ray of ordinary *white* light is known to be very complex, consisting not only of transverse vibrations in every plane, but of waves of thousands of different lengths associated together, and moving forward so fast that many hundred millions of millions of each separate kind of constituent waves enter the eye in a single second. Notwithstanding this infinity of complex vibrations, we possess the means of separating the constituents of such a ray of light, dividing it into thousands of colored rays by means of the prism or interference grating, and splitting and twisting it in the most extraordinary manner by means of the polariscope. It is

Photo Club de Paris, March, 1892, p. 83.

only by separating the ordinary ray of light into its constituent parts, and exposing the sensitive plate in the camera to each separate kind of vibration, that we can arrive at a clear understanding of the capabilities of the photographic process, for the kind and rate of vibration that produces chemical change in some substances does not affect others, and the effect of one constituent of a ray of light may under some circumstances be neutralised by the opposite effect of another constituent of the same ray.

Our first step in the analysis of a ray of white light may be made by the aid of the prism. Of course, we cannot, in practice, handle a single ray of light, which is something infinitely slender; but the constituents of a bundle of rays, or a "pencil" of light, can be reflected, refracted, dispersed, split up, and twisted like a single ray. If we place in the slide-holder of the projection lantern a metal plate with a narrow slit in it, which would show as a narrow line of light on the screen, a prism placed in front of the objective will separate the different wave-lengths as we would open a fan, changing the narrow line of light into a broad ribbon of colors, varying in hue from red, through orange, yellow, green, and blue to violet. It is thus proved, by this familiar illustration, that white light is a mixture of colored rays.

We know that in white light most objects show color, and a single experiment shows the cause of most colors. If we place a red glass in the path of the rays, we shall see that it is red because it absorbs, or destroys, nearly all of the rays except the red. It will help this experiment to project the colored

glass directly upon another part of the screen, so that the color of the glass and its analysis by the prism can be seen at the same time. The glass and the band in the spectrum are in this case of the same color. Similarly, a green glass is green, because it transmits chiefly the green spectrum rays, and the color of the glass and of the band in the spectrum is again the same. Most of the colors in nature are not so simple as these. Pink is a mixture of all of the spectrum rays except the green or yellow-green; and in this case the color of the object is not like any part of its spectrum. Yellow is also a very impure color, the most brilliant hues consisting of a mixture of all of the spectrum rays except blue and violet. It is really most remarkable that so many people should continue to regard yellow as a "primary" color, when such a simple absorption experiment as this proves that the most brilliant yellow may be made up of nearly all of the green, yellow, orange, and red rays of the spectrum.

Although most of the colors in nature are due to specific absorption of some of the constituents of ordinary white light, many objects which ordinarily transmit all of the spectrum rays as freely as ordinary window-glass, show the most brilliant and beautiful colors conceivable when spread out in very thin films, as in the soap-bubble or in the polariscope, in which split rays are twisted or again divided and made to interfere with each other, so as to neutralise or suppress some wave-lengths, so giving rise to the well-known colors of polarised light.

Everybody here is of course perfectly familiar with these experiments; but there may be some interest in seeing them

performed with a special lantern attachment which I have devised—an open front, carrying all of the optical attachments, and sliding smoothly to centering stops, so that we may have either ordinary slide projection, the spectrum, and a comparison patch, the polariscope, or a microscope, at a moment's notice.

The polarisation of a ray of light does not, under ordinary circumstances, affect its photographic action, and is of interest in this connection chiefly as a further illustration of the complex structure of the light ray, and a pretty example of the production of colors in the absence of specific absorption or prismatic dispersion.

Having analysed the ray of light, we are now in a position to intelligently consider its photographic action. Scientific men used to divide the spectrum into three parts, which were called heat, light, and actinism, although it was supposed that the heat rays blended with the light rays at the red end of the spectrum, and the actinic rays with the blue and violet at the other end. The old and long-standing reproach against monochrome photography, that it rendered dark colors, such as blue, in light monochrome, and light colors, such as yellow, in dark monochrome, was due to the fact that the ordinary photographic sensitive plates are, under the usual conditions of use, acted upon chiefly by the so-called actinic rays, while the eye is impressed chiefly by the more luminous rays towards the other end of the visible spectrum.

This defect in the photographic process has been overcome partly by increasing the color-sensitiveness of the photographic plates by treatment with certain dyes, and partly by the use of color-filters, which cut out some or all of the rays which are

ordinarily too active. With some of the undyed extremely rapid dry plates, the use of suitable color-filters alone is sufficient to secure correct rendering of color values in monochrome; but, owing to their comparatively feeble color-sensitiveness, it is necessary to give very long exposures. With the dyed plates, "orthochromatic" photographs can be secured with lighter color filters and very much shorter exposures, though not as short as are ordinarily given in portrait and hand-camera work.

I exhibit a series of spectrum photographs showing the colour-sensitising action of certain dyes. These photographs were made a long time ago, on collodio-bromide emulsion plates, one used plain, and the others sensitised with erythrosine, cyanine, and chlorophyl. The ordinary plate is sensitive chiefly to the violet blue, violet, and ultra-violet rays; the erythrosine sensitises for the yellow-green, and the chlorophyll for all parts of the visible spectrum except the extreme dark red. These photographs make it evident that all of the light rays have the property of actinism, that is, the power to produce chemical change. It will also be seen that, having dissected the ordinary light ray, we have also found the means for controlling the relative action of its constituents in the photographic process. Given a plate sensitive to all of the spectrum rays, we can stop the action of any not wanted by any interposing suitable color filters, for the construction of which there is an endless variety of colors to be found in the coal-tar dyes and their combinations; and we can in some cases greatly facilitate the selection of suitable color-filters, by using color-sensitisers, which act only or principally in the part of the spectrum in which the chief action is desired. It follows that we can make photo-

graphs by the action of any group of visible spectrum rays that we may select, and in any relative proportions that we may desire. The adaptation of this means to the production of photometrically accurate representations of color values in monochrome photographs is very simple, it being only necessary to use a combination of sensitive plates and color filters which will (with quartz prisms and photographic lens) secure photographs of the spectrum showing density curves like a graphic curve, representing the relative visual intensity of the different spectrum rays. A consideration of the trichromatic nature of color vision will show how the same means, applied through the production of three negatives instead of one, is adapted to record and reproduce the colors themselves.

We have seen that the spectrum colors change as the wave-length of the light varies; but we now come to a fact of the greatest importance in its bearing upon the subject of color reproduction by photography. Color does not depend upon wave-length only. Although the colors of the different parts of the spectrum are fixed (depending upon the wave-length of the respective ray), it is substantially true that all of the colors of the spectrum, and therefore all the colors in nature, are, as Maxwell said, "equivalent to mixtures or three colors of the spectrum itself."

The Young-Helmholtz theory of color vision explains this fact by assuming that there are three fundamental color sensations—a red, a green, and a blue violet—which may possibly be due to three kinds of nerves in the eye, and that all other colors are compound sensations. Clerk-Maxwell assumed

that the spectrum red, green and blue violet rays excited almost exclusively the respective fundamental color-sensations, and that all other visible spectrum rays excited simultaneously two fundamental sensations. By means of his now celebrated "color box," he made measurements of spectrum color mixtures, and plotted curves showing in what proportions his so-called fundamentals combine to reproduce the other hues of the spectrum.

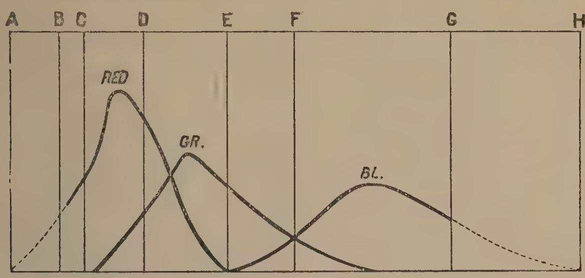


FIG. 16.—Maxwell's Color Curves.

The photochromoscope system of color photography is based upon, and is substantially an application of these facts. Three photographs of the object are made, because three colors are required to reproduce all others; and each photograph is made by the joint action, in due proportion, of the respective fundamental color, and all other hues into which it must enter in the reproduction; but each photograph is afterwards seen by light of the fundamental color only, and the three are blended into one composite image. The application of the color-mixture curves is most readily shown by assuming that we wish to reproduce the spectrum itself. We know that, in order to do so, we

must mix the three colors which Maxwell assumed to be the fundamentals, and that for each part of the spectrum we must mix them in the proportions indicated by the relative height of the respective color-curves on the diagram in that part. The lantern positives must distribute the respective fundamental colors upon the screen, in the proportions indicated by the color-mixture curves. For instance, the positive for the red should be perfectly transparent for that part of the spectrum where the curve of the red is highest, graduating off to practically complete opacity, on the red side about Fraunhofer line, A, and on the green side at the line E. Similarly, the positives representing the distribution of the green and blue-violet elements should correspond to the second and third curves of the diagram. It is evident that three such images, projected with red, green, and blue-violet lights, would combine to form a correctly colored and graduated representation of the spectrum upon the screen. Such positives can be obtained by contact printing from negatives having a distribution of density corresponding to the color-mixture curves, and such negatives can be obtained by photographing the spectrum with color-sensitive plates exposed through correctly-adjusted color filters. A set of three negatives of any object, if made with plates and color filters adapted to secure such photographs of the spectrum (and correctly exposed and developed), will constitute a true and permanent color-record of that object, a positive copy of which record may at any time be translated into accurate color by triple lantern projection, but far more readily and perfectly in the photochromoscope, which I shall presently describe.

It has been known for years that Maxwell's color curves are

not the true color-sensation curves. The purest green of the spectrum is itself a compound-sensation color, and it is not possible to excite the fundamental green sensation alone in the eye of a person who has normal color-vision. In the photochromoscope system we are limited to the use of the fundamental red, the fundamental blue-violet, and a compound-sensation green for our reproduction colors. We have, therefore, no use for the true color-sensation curves, which call for a fundamental green reproduction color, which, to normal vision, does not exist; we know it only as it is diluted with white, or red, or both, in the spectrum. The use of the sensation curves would as I explained in a communication to the "Photographic Times Annual" (New York) for 1895, introduce a fatal defect in the process. We are concerned not with the mixtures of unrealisable fundamental sensations, but with the mixtures of actual spectrum colors, which must, however, be taken from those parts of the spectrum which excite most exclusively the respective fundamental sensations. Maxwell's curves represent the measurements of such mixtures, but with red and blue colors rather too far removed from the extreme ends of the visible spectrum to give the most accurate results which are possible. Maxwell's green cannot be much improved upon for this purpose; for although it does not excite exclusively the fundamental green sensation, the true sensation curves show that it excites that sensation relatively more than does any other hue of spectrum green. At F $\frac{1}{3}$ E, where the fundamental green sensation, according to Koenig's color-sensation curves, is degraded by admixture of white only, the total degradation is about twice as great as at E. With Maxwell's green, we get the least possible amount of

degradation of color, and most of that confined to the darker portions of the spectrum, at the blue end; with the green at F $\frac{1}{3}$ E, there is less degradation of green-blues, but more degradation altogether, and much of it in the more luminous parts of the spectrum.

If we employ purer red and blue-violet colors in the lantern than those used in Maxwell's measurements, we must alter his curves slightly in order to obtain the most accurate results; but neither in the photochromoscope nor in any other application of this principle for photographic color reproduction has it been found practicable to employ much purer colors than Maxwell's "fundamentals;" and as the measurements should be made with the colors actually employed for reproduction purposes, color-filters proved according to Maxwell's curves yield results in which any degradation of color is reduced to the practicable minimum. Nowhere is the deviation sufficient to be noticeable under ordinary circumstances, although special tests have shown that the curves may be slightly modified to advantage.

That all of the visible spectrum rays should act in producing the color record, and that only the pure red, green and violet-blue rays should be used in the synthesis, is clearly proved and has now been recognised by authorities. The practical importance of observing these conditions, may be shown by considering what would be the effect of employing the pure color-filters in making the negatives, or the color curve filters for synthesis, in particular cases.

If we photograph the spectrum itself with color-filters transmitting only red, green, and blue-violet rays, it is evident

that the orange, yellow and green-blue portions of the spectrum cannot act in producing the negatives, and will therefore be absent in the reproduction, which will consist of three widely separated bands of pure color; it is necessary to use the color-curve filters in order to permit action by the intermediate spectrum rays, and the subsequent blending of the pure colors, where necessary, to represent them in the reproduction. In the reproduction of very many of the ordinary compound colors in nature, negatives made with the pure color-filters would introduce defects not less real if not always so obvious.

The use of the color-curve filters for synthesis, would cause a pure red to be represented in the reproduction by a mixture of all of the spectrum rays between A and E, which might make either a yellow, an orange, or a scarlet, depending upon the relative red sensitiveness of the plates for which the color-filter was proved. Pure green would be represented either as an apple-green, yellow-green, or yellow—it being possible to obtain correct negatives with filters of any one of these colors, on plates of one kind or another. Blue-violet would necessarily be very impure for similar reasons. In short, pure red, green, and blue-violet are colors which cannot be adequately represented by color mixtures.

Some writers have advocated the use, for both photographic and synthetical purposes, of color-filters, which are a compromise between the pure-color and color-curve filters, in order to simplify the practice of the method. Such a suggestion naturally appeals to slovenly operators, who care more for ease than accuracy; but it will not favourably impress the scientific

mind; and its adoption would evidently deprive the method of any value which it might have in application to scientific work, or even to high-class art reproduction.

Since the difference between color-filters suitable for the negative process, and color-filters suitable for synthesis has been pointed out, it appears so obvious, that it is difficult to believe that this difference was not recognised by Maxwell; but if it was, the report of his lecture was inadequate, since we do not find in it any statement to that effect. It is quite possible that we may have here an example of what is, in patent law phraseology, termed "insufficient publication."

Composite color photography, so long as it required the production of three separate negatives, by separate exposures, and three separate positives, to be projected by a triple lantern, no matter how perfect the results, could not be of much practical importance; but I have contrived such simple and inexpensive apparatus as should, when purchasable, make the method practically available, even to the amateur photographer. A camera which is probably no more complicated than a "kodak" makes the negative images which constitute the color record on a single sensitive plate, at one exposure; and a contact positive from this negative, when cut in three and mounted on a folding cardboard frame, can in a moment be dropped into another optical instrument, the photochromoscope, which, as well as the camera, may be made stereoscopic, and is even then not much larger than some of the ordinary hand stereoscopes. The color record, or chromogram, when viewed in this instrument, realises a reproduction which is so satisfying to the eye that the un-

initiated imagine that it is the object itself at which they are looking. It is far more realistic than a mere color photograph on a flat surface would be, because the image is free from surface reflections and distracting surroundings, and is in perfect stereoscopic relief.

It is true that this is not exactly the kind of color photography that the world has been looking for. Although in practice given the special apparatus to work with, the operation of the process is above criticism for ease and simplicity, and the result is perfectly satisfying to the eye, it is not what many people have desired, because it does not produce fixed colored images, which can be framed and hung upon the wall, or in a window, or inserted in a book. Fixed color prints can be made from the photochromoscope negatives, but only by so greatly complicating the procedure as to make it comparatively impracticable.

Ducos du Hauron was the first to produce color-prints of this character, but his method was not successful. The defects in his results were due to several causes, among which may be mentioned:—(1) A wrong theory of color selection; (2) the production of three negatives by successive exposures on separate and different plates, by which means it is seldom possible to perfectly equalise exposure and density; (3) the prints were made separately, in differently pigmented gelatine, by which means it is almost impossible ever to make the three of corresponding gradation and depth of color, as is absolutely necessary in order to obtain accurate results; (4) the prints were transferred to superpose them, an operation which usually results in unequal expansion and imperfect register.

I succeeded in eliminating these defects. My negatives were made according to the true principle, and at one exposure, on a single sensitive plate. My prints were made by a single exposure on a single sheet of bi-chromatised gelatine on a support of thin celluloid, and were colored, after cutting apart with scissors, by immersion in aqueous solutions of suitable dye-stuffs. This method of coloring the prints has the very important advantage that the coloring can be carried to exactly the right depth by a little experiment; and an over or under-colored print can be made right by re-immersion in the dye or in water. I showed permanent color-prints made in this way in Philadelphia in 1890, and here in 1894. The results are by no means equal to the photochromoscope image, and the method is far too complicated and difficult to compete with the photochromoscope system for general adoption. The successful application of the principle to the production of color-prints by machine printing involves still more serious difficulties and defects.

Who can doubt that the production of a perfectly life-like representation, by a simple and easy process, even though requiring the use of a special stereoscope to complete it, is of vastly greater importance than the production of flat color-prints by complicated, difficult, expensive, and yet comparatively imperfect methods?

The form of the photochromoscope suggests steps of stairs. It was first made with three steps, and on the top of each step was placed one image of the chromogram, which is made in sections hinged together, so as to fold up The model was after-

wards reduced in size, and made more powerful, by having only two steps, the third image standing upright against the front of the lower step. The red image, lying horizontally on the top step, is seen by reflection from the first surface of a transparent mirror of cyan-blue colored glass, which stands underneath it and in front of the eye, inclined at an angle of 45 degs. The blue-violet image lies upon the second step and is seen (through the cyan-blue glass above-mentioned) by reflection from the first surface of a transparent mirror of green or yellow glass, which is also inclined at an angle of 45 degs. under the image. The green image, standing upright against the lower step, is viewed directly through the cyan-blue and green (or yellow) transparent mirrors, both of which transmit the green light. By this means the three images are so blended as to appear as one to the eye. The use of colored glass reflectors, which is my own invention, avoids double reflections, and consequent doubling of outlines, it being only necessary to use glasses, the substance of which absorb light of the color which they are intended to reflect from the first surface. It is possible to use instead a special thinly silvered mirror; but such silvered transparent mirrors will not bear rubbing to clean them, and can hardly be safely placed in a popular instrument, which must be cleaned at intervals and kept in order by ordinary purchasers. The photochromoscope with colored glass reflectors can be cleaned and kept in order by a child.

The photochromoscope image must be seen to be appreciated. Scientific men who had admitted that the photochromoscope system should be competent to reproduce the colors of objects, assured me that they were, nevertheless, positively

startled by the realism of the result. Thousands of people have now expressed their surprise and admiration, but this counts for very little in the minds of most of those who have yet to see it. It is so much a case of "seeing is believing" that it is a waste of time to discuss the subject with anybody who has not yet seen the results in the small table photochromoscope.

Even those who have seen and recognised the beauty and perfection of the photochromoscope reproductions often ask—and it is perfectly reasonable that they should ask—"What useful purposes will this invention serve?" This question always reminds me of the story of Faraday, who, when asked what was the use of a certain new discovery, retorted by asking "What is the use of a new-born baby?" I can, however, suggest a few important applications for the photochromoscope,artistic, industrial,and educational. In the first place, the works of the old masters can be reproduced by the instrument with every touch and tone of color depicted as in the original masterpiece. The color records, occupying little space, can be stored in a small cabinet, or readily sent from place to place for purposes of reference or exchange, affording to the artist opportunities to study at his leisure, and in the quiet of his own studio, the technique of the acknowleged masters of his profession, although the original paintings may not be accessible to him. Decorative work of all kinds can be as faithfully reproduced for the use and study of designers—tapestried hangings, mural paintings, stained glass windows, furniture, pottery, enamels, &c. Landscapes from all parts of the world and rare and valuable objects of scientific interest can also be included in the cabinet of color records. It will even aid in medical diagnosis by acquainting the practitioner with the

actual appearance of skin diseases, and their changes from day to day under various conditions which he has not met with in his own practice; I shall not be at all surprised if its value to the science and practice of medicine shall prove to be incomparably greater than that of the so-called "new photography" with the Röntgen rays. It will even prove of considerable value, especially in that country of great distances, America, to many commercial travellers, enabling them readily to show to their customers the exact appearance, in color, of objects of merchandise which are too large or too valuable to be economically carried about as samples. It will also probably become an adjunct to every school and college in the world, not only as an illustration of applied science and a graphic demonstration of the principles of color vision, but because it will afford, by means of color records of rare natural history objects and peculiar cabinet specimens, a virtual extension of the school's collection which may add enormously to its educational value. Its application to portraiture is too obvious to call for comment. Still other useful applications have already been suggested, and new ones doubtless will be, as it becomes better known.

The perfected photochromoscope camera consists of a casing which receives a dark slide at one end, and has a single achromatic lens of large diameter, in a sliding tube, at the other. Behind the lens is a series of two transparent and four silvered reflectors, arranged to divide each light ray into three, so that three images are formed, identical in size and perspective, on different parts of the 7 by 5½ sensitive plate. This arrangement permits of a separate lens diaphragm for each image, so that after the color filters are inserted, the exposure for the different

images can be perfectly equalised. This comparatively simple instrument is made stereoscopic by means of an external mirror attachment which is the invention of Mr. Theodore Brown, of Salisbury, and called the "stereoscopic transmitter." This attachment not only permits of securing three stereoscopic pairs of images with one lens, but at the same time reverses and transposes the images, which is necessary in order to bring them right in the photochromoscope.

Any moderately skilful amateur photographer, provided with this camera, should be able to make original chromograms with very little more trouble than is involved in the production of original lantern slides. For portrait work, a simpler camera can be provided, with three separate plates and larger diaphragm apertures; but more skill and experience is necessary to operate the process successfully, when the images are exposed and developed on separate plates. My aim has been to make the successful operation of the process as nearly automatic as ordinary photography, and the camera which I show accomplishes this for all subjects not requiring short exposures.

[The Chairman, Lyonel Clark, said, as there did not seem much inclination for discussion, he would take the opportunity, while Mr. Ives was arranging the photochromoscopes on the tables, to move a vote of thanks to him for his very interesting paper, and those present would then have an opportunity of seeing the photographs both in color and relief. Most of them were accustomed to seeing stereoscopic slides, but interesting and curious as the result was, he thought the effect on the mind

always was that you were looking at a little clay model—whether it were a basket of fruit or a statue, it was not the real thing. The total absence of all color, the mere yellow or brownish purple of the print, gave the effect of a model, though it was perfect in relief and detail. But in this case you saw the same model endowed with the colors of nature, and it then ceased to look like a model, and you thought you were looking at the real thing. Some of Mr. Ives' slides which he had seen were the most realistic things in the world—you could not really tell whether you were looking at the real thing or an image of it.]

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Part Two.

THE NATURE OF LIGHT.

By Professor Von Bezold.*

The most varied experiments and profound theoretical investigations, which again were proved and confirmed by experiments, step by step, compel us to form a conception of the nature of light, similar to that which we have already had for a long time of the nature of sound.

By these investigations it has been demonstrated that the sensation of light is produced by the vibration of the so-called ether, a medium which fills the whole space of the universe, and penetrates all bodies. These vibrations are propagated with an exceedingly great velocity in space and in transparent bodies, and are thus the cause of the origin of the so-called wave-motions. A good representation of such wave-motions is given by the circles produced by a stone thrown into the water, or perhaps still better by the beautiful undulatory motion which may be observed when the wind sweeps over a field of ripening corn. In the one case the particles of water, in the other the ears of corn, execute one after the other, the same or a similar swinging movement; and this vibration is called wave-motion. But very different kinds of such wave-motion may be propagated simultaneously through the same medium, without essentially interfering with one other. If, for example we throw two stones into the water at a short distance from each other, each

*The Theory of Color. L. Prang & Co., Boston

of them will produce its circles, and we can without difficulty follow the course of the waves of these circles even in those places where they overlap one another.

The multitudinous systems of waves produced by the instruments of a full orchestra are propagated without impediment, not only through the air, but even through the narrow acoustic duct of the ear; and a practised ear is capable not only of following each part, but even the playing of each single instrument in a brilliant symphony.

In reality, each individual particle of air naturally makes only one motion in any one moment of time; but this motion is qualified by all the separate motions which act upon such a particle, and by suitable apparatus these compound motions can again be resolved into their elements. We have such an apparatus for the waves of sound in the human ear, for the waves of light in the prism. The ear or the prism separate the waves of air or of ether, which impinge on them, into waves, the vibrations of which take place in accordance with a simple law, and in a manner similar to the vibrations of the pendulum. Between such simple vibrations there cannot be more than two points of difference; they can differ, on the one hand, in the time which passes while one vibration is executed, and, on the other hand, in the distance which is travelled over by one of the particles in motion while making one vibration.

The time necessary for the completion of one vibration is called the period of vibration. Upon the length of this period depends, in acoustics, the pitch of the sound, in a musical sense; in optics, the hue of the colour.

The length of path travelled over, or, what is the same, the greatest distance from the point of equilibrium reached by the particle during one vibration, that is to say, the amplitude, determines, in the one case the intensity of the sound, in the other the brightness of the ray of light.

In the ray which emerges from the prism, the vibrations are executed according to the simple law just alluded to; and the differences between the variously colored rays arise only from the difference in the length of the period of vibration. But the duration of this period in the vibrations of light is exceedingly minute. The impression of red light caused by one end of the spectrum is produced by vibrations of which 400 trillions are executed in one second, while as many as 790 trillions of vibrations correspond to the violet end of the spectrum. The numbers of the vibrations corresponding to all the other rays which lie between these two ends of the spectrum, will also be found to lie between the two numbers just mentioned.

THE ACT OF SEEING.

By Professor Von Bezold.*

The transparent media of the eye act upon the light which enters them, in a manner similar to the lenses of the camera employed by the photographer. They produce in the interior of the eye an image of the objects of the outer world. This image, under normal conditions, is projected upon an exceedingly delicate membrane, which is spread out in the inner part of the eye, and is called the retina. The retina is composed throughout of nervous elements, most cunningly constructed, each element being connected with the brain by fine nerve-fibres, which together form the so-called optic nerve. These elements are excited by light impinging on them.

The processes which a ray of light, or a bundle of such rays, is subjected to, in so far as they take place outside of the eye, are of a purely physical character. The passage of the rays through the transparent media of the eye is likewise regulated simply according to the laws of inanimate nature, and upon the retina of an eye freshly cut from a dead animal; the image is produced as sharply and as clearly as upon that of a living eye.

The processes on the retina, on the contrary, are of quite another kind. They are based upon the peculiar activity of the living organism, and their investigation instead of being a part of the domain of physics, belongs to physiology. When two pigments are mixed upon the palette, the light emanating from them

* The Theory of Color. L. Prang & Co., Boston.

passes, before it reaches the eye, through a physical process, the laws of which are completely independent of the construction and of the activity of the sensitive organism. If, on the contrary, light of various colors falls simultaneously upon one of the elements of the retina, the different impressions must be blended into one upon the retina, and it is even possible that the blending does not take place until after these impressions have reached the brain.

In seeing, there are furthermore associated with these processes of a physical and a physiological nature the activities of the reasoning faculty and of the judgment. The image of the outer world is formed upon a child's retina quite as clearly as upon that of a grown person, and the sensitive elements are the same in both cases; nevertheless, the child reaches out its hands after the sparrow upon the roof, or will even attempt to catch the moon. In the course of time however, the child, by means of the small differences between the images in the two eyes, which are caused by the difference in the position of each eye in relation to the objects existing outside of it, and by availing itself of various other circumstances, acquires the faculty of judging of distances, and therefore immediately *sees* things in their proper position.

In the theory of color the investigator must deal at one time with purely physical facts, that is to say, with facts which are independent of the living organism; then again with physiological processes, that is to say, processes which are entirely pecular to this organism; and finally there must be added to these the activity of the reasoning faculty, the judgment, and psychological and æsthetic questions.

THE THEORY OF COLOR.

By Professor Pickering.*

Colors are sometimes divided by artists into primary, secondary, and tertiary; the first term being applied to the colors red, yellow and blue of the spectrum. The other colors of the spectrum are called secondary or binary, since according to Brewster's theory, each is composed of two primary colors, while tertiary colors are formed by combining two secondaries. These terms are based on the erroneous theory that the three elementary color sensations are inherent in the light, and not in the eye. In reality, all the colors of the spectrum are equally primary, being composed of rays of uniform wave-length, and all ordinary colors are formed of rays from every portion of the spectrum, differing only in the proportions in which they are combined.

In considering the subject of color, or the sensation produced when waves of different lengths fall on the retina, we must recollect that this phenomenon is wholly subjective. Accordingly, our knowledge of the aspect of these waves depends wholly on the construction of the eye. Young, in 1802, was the first to show that all the phenomena of color could be accounted for by supposing that the retina contained three kinds of nerves, each sensitive to waves of a certain length, that is, to a particular color. Other colors may be formed by exciting these nerves unequally. Thus a ray of yellow light will

* The Theory of Color. L. Prang & Co., Boston.

excite both the nerves sensitive to red and those sensitive to green, or will produce on the eye the same effect as if red and green rays are received together. In other words, red and green if mixed produce yellow, and not white, as is commonly supposed. The theory of Young was, however, quite forgotten until again brought forward in 1853, when the experiments of Helmholtz and Maxwell added greatly to their probability, and showed that the three primary colors are red, green, and dark blue or violet.

The impression of color is wholly subjective or dependent upon the formation of the eye by which it is viewed. As far as the light itself is concerned, the waves of different colors are infinitely varied as regards their length, but as the eye has only three tests for them by its three sets of nerves, our judgment is formed by the relative excitation of these three sets.

THE EFFECT PRODUCED UPON COLOR BY A CHANGE OF LUMINOSITY.

By Professor Rood.*

In our study thus far of colored surfaces it has been tacitly assumed that their action on the eye is a constant one, and that a red surface, for example, will always appear red to a healthy eye as long as it remains visible. In point of fact, however, this is not quite true, for it is found that colored surfaces undergo changes of tint when they are seen under a very bright or a very feeble illumination.

Artists are well aware that scarlet cloth under bright sunshine approaches orange in its tint; that green becomes more yellowish; and that, in general, a bright illumination causes all colors to tend somewhat towards yellow in their hues. Helmholtz, Bezold, Rutherford, and others have made similar observations on the pure colours of the prismatic spectrum, and have found that even *they* undergo changes analogous to those just indicated. The violet of the spectrum is easily affected: when it is feeble (that is dark), it approaches purple in its hue; as it is made stronger, the color changes to blue, and finally to a whitish grey with a faint tint of violet-blue. The changes with the ultramarine blue of the spectrum follow the same order, passing first into sky-blue, then into whitish-blue, and finally into white. Green as it is made brighter passes into yellowish-green, then into whitish-yellow; for actual conversion into white it is necessary that the illumination should be dazzling. Red resists these changes more than the other colors; but if be it made

*Modern Chromatics, International Scientific Series.

quite bright, it passes into orange and then into bright yellow. It is remarkable that these changes take place with the pure colors of the spectrum.*

We pass now to the changes which occur when the intensity of colored light is made very feeble. Von Bezold has made some interesting observations of this character on the colors of the spectrum. With a very bright prismatic spectrum he was able to see a pure yellow near D, and a whitish-blue near F, the other colors being in their usual positions. When the illumination was only moderately bright, the yellow space diminished and became very narrow; the ultramarine blue vanished and was replaced by violet. With less illumination, the orange-yellow space assumed the color of red lead, and the yellow vanished, being replaced by a greenish tint; the cyan blue was replaced by green, the blue and ultramarine blue by violet. The spectrum at this stage presented scarcely more than three colors, red, green, and violet. With a still lower illumination, the violet vanished, the red became red-brown, and the green was visible as a pale green tint; then the red-brown disappeared, the green still remaining, though very feeble. With still less light, even this suggestion of color vanished, and the light appeared simple grey.

The tendency of these experiments is evidently just the reverse of what was observed when the illumination was very bright. In that case the colored light as it increased in brightness gradually set all three sets of nerves into action, and the result was white or yellowish-white; but here the action of the colored light as it grows feebler is more and more confined to a single

* [Abney has proved that if the spectrum is a perfectly pure one, the red below B½C and the violet above G¾H do not undergo these changes].

set of nerves. From this it results that those color-sensations which are due to the joint action of two sets of nerves speedily diminish when the color is darkened, and are replaced by the primary sensations, red, green, or violet. The sensation of orange is produced by those light-waves in the spectrum which have a length such as to enable them to stimulate the red nerves strongly and the green nerves to a lesser degree; hence, when orange-colored light is made very weak, it fails to act on the green nerves while still feebly stimulating the red, and consequently the sensation of orange passes over into red. For similar reasons the sensations of yellow and greenish-yellow pass into green, as do also those of greenish-blue and cyan-blue; in the same way the sensations of blue, ultramarine-blue, and violet-blue pass into violet. It is quite evident that these changes furnish another argument in favour of Young's theory of color, and also tend to approve the selection of red, green and violet as the fundamental color sensations.

Changes in luminosity produce still other effects which are quite remarkable. If we arrange by ordinary daylight sheets of red and blue paper, which have as far as we can judge about the same degree of luminosity, and then carry them into a darkened room, we shall be surprised to find that the blue papers appear brighter than the red. Indeed, the room may be so nearly darkened as to cause the red paper to appear black, while the blue still plainly retains its color. By similar experiments it can be proved that red, yellow and orange-colored surfaces are relatively more luminous when exposed to a bright light than blue and violet surfaces; the latter, on the other hand, have the advantage when the illumination is feeble.

GRADATIONS OF COLOR IN NATURE.

By Professor Rood.*

One of the most important characteristics of color in nature is the endless, almost infinite gradations which always accompany it. It is impossible to escape from the delicate changes which the color of all natural objects undergoes, owing to the way the light strikes them, without taking all the precautions necessary for an experiment in a physical laboratory. Even if the surface employed be white and flat, still some portions of it are sure to be more highly illuminated than others, and hence to appear a little more yellowish or less greyish; and, besides this source of change, it is receiving colored light from all colored objects near it, and reflecting it variously from its different portions. If a painter represents a sheet of paper in a picture by a uniform white or grey patch, it will seem quite wrong, and can not be made to look right till it is covered by delicate gradations of light and shade and color. We are in the habit of thinking of a sheet of paper as being quite uniform in tint, and yet instantly reject as insufficient such a representation of it. In this matter our unconscious education is enormously in advance of our conscious; our memory of sensations is immense, our recollection of the causes that produce them utterly insignificant; and we do not remember the causes mainly because we never knew them.

These ever present gentle changes of color in all natural objects give to the mind a sense of the richness and vastness of

*Modern Chromatics, International Scientific Series.

the resources of Nature; there is always something more to see, some new evanescent series of delicate tints to trace; and even where there is no conscious study of color, it still produces its effect on the mind of the beholder, giving him a sense of the fulness of Nature and a dim perception of the infinite series of gentle changes by which she constantly varies the aspects of the commonest objects. This orderly succession of tints gently blending into one another, is one of the greatest sources of beauty that we are acquainted with, and the best artists constantly strive to introduce more and more of this element into their works, relying for their triumphs far more on gradations than on contrasts.

Ruskin, speaking of gradations of color, says: "You will find in practice that brilliancy of hue and vigour of light, and even the aspect of transparency in shade, are essentially dependent on this character alone: hardness, coldness and opacity resulting far more from *equality* of color than from nature of color." In another place the same author, in giving advice to a beginner, says: "And it does not matter how small the touch of color may be, though not larger than the smallest pins head, if one part of it is not darker than the rest it is a bad touch; for it is not merely because the natural fact is so that your colors should be gradated; the preciousness and pleasantness of color depends more on this than on any other of its qualities, for gradation is to color just what curvature is to lines, both being felt to be beautiful by the pure instincts of every human mind, and both, considered as types, expressing the law of gradual change and progress in the human soul itself. What the difference is in mere beauty between a gradated and ungradated

color may be seen easily by laying an even tint of rose-color on paper and putting a rose-leaf beside it. The victorious beauty of the rose as compared with other flowers depends wholly on the delicacy and quantity of its color-gradations, all other flowers being either less rich in gradation, not having as many folds of leaf, or less tender, being patched and veined instead of being flushed."

THE CHARM OF COLOR.

By Professor Rood.*

The power to perceive color is one of the most indispensable endowments of our race; deprived of its possession, we should be able not only to exist, but even to attain a high state of intellectual and æsthetic cultivation. Eyes gifted merely with a sense for light and shade would answer quite well for most practical purposes, and they would still reveal to us in the material universe an amount of beauty far transcending our capacity for reception. "But over and above this we have received yet one more gift, something not quite necessary, a benediction as it were, in our sense for and enjoyment of color." It is hardly fair to say that without this gift nature would have appeared to us cold and bare; still, we should have lost the enjoyment of the vast variety of pleasant and refined sensations produced by color as such and by color combinations; the magical drapery which is thus cast over the visible world would have given place merely to the simpler and more logical gradations of light and shade. The love of color is part of our constitution as much as the love of music; it developes itself early in childhood and we see it exhibited by savage as well as cultivated races. We find the love of color manifesting and making itself felt in the strangest places; even the most profound mathematicians are never weary of studying the colors of polarised light, and there can be no doubt that the attractive power of color has contributed to swell the mathematical literature of

*Modern Chromatics, International Scientific Series.

this subject. The solar spectrum with its gorgeous tints was for many years before the discoveries of Kirchhoff and Bunsen a favourite, almost a beloved subject of study with physicists; the great reward of this devotion was withheld for nearly half a century; divested of its color-charm, attracting less study, the spectrum might still have remained an enigma for another hundred years.

Color is less important than form, but casts over it a peculiar charm. If form is wrongly seen or falsely represented, we feel as though "the foundations were shaken;" if the color is bad, we are simply disgusted. Color does not assist in developing form; it ornaments and at the same time slightly disguises it; we are content to miss some of the modelling of a beautiful face for the sake of the color-gradations which adorn and enliven it.

PHOTOGRAPHY IN COLORS.

From the London "*Daily News.*"

Photography in colors no longer means the photograph printed in colors, nor yet the "colored photograph," both of which terms are apt to be associated in the artistic mind with some rather painful as well as endurable experiments. As we speak of it to-day, it means the practical results of a truly important invention completed after many years of persevering efforts by Mr. Frederic Ives, who has just read, at the galleries of the Fine Art Society an explanatory paper with accompanying illustrations, and is now giving the public an opportunity of judging for themselves as to the interest of his discoveries. The invention is the Krōmskōp for the reproduction, in the absolute colors of nature, of all objects photographed with a specially designed camera, and moreover by a permanent process, so that the traveller and student will be able to store up not only impressions of beautiful or otherwise interesting things, but the actual presentment of them with the appearance of color and texture added to form. At present the system is perfected for 'still life,' and when a little further developed will, it is expected, be equally available for perpetuating living originals; so that we shall be able to carry in a box a few inches square, not only records in facsimile of treasures of art, but the figures of our friends, their surroundings, and anything else that it may be desirable to store up for affectionate remembrance. When the Krōmskōp arrives at this point of accomplishment, then bid farewell to the minor poet; his lady-

love will no longer live in dreams, for he will preserve in a box the very sheen of her hair, just as in the present exhibition may be seen the gloss on the butterfly's wing, the bloom on the petal of a flower, the very tone of old ivory and inlaid pearl from the cabinet of the collector. The mere craving for a method of photography in natural colors is nearly as old as that pioneer of the camera's image, the Daguerreotype, which most of us revere for the sake of the ancestors that have been handed down through it. . . . The camera makes the negative images which constitute the color record on a single sensitive plate, at one exposure ; and a contact positive from this, when cut in three and mounted on a folding cardboard frame, is dropped into the Krōmskōp, which, as well as the camera, is stereoscopic. When viewed through this instrument it is no exaggeration to say that the object looks quite real.

PRICE LIST

OF THE

PHOTOCHROMOSCOPE SYNDICATE, LIMITED.

	£	s.	d.
The Krōmskōp	5	0	0
Carrying Case	0	15	0
Kromograms (list free), each	0	5	0
The Krōmskōp Lamp	2	2	0
The Junior Krōmskōp	3	10	0
Carrying Case for Junior Krōmskōp	0	12	0
Single Kromograms (for Junior Krōmskōp), each ...	0	3	6
Junior Krōmskōp Lamp	1	12	0
The Lantern Krōmskōp, with six Slides and Carrying Case	10	10	0
Extra Slides for Lantern Krōmskōp, each ...	0	5	0
Small Multiple Back, with Color Screens and one Double Dark Slide (making pictures the right size for the Junior and Lantern Krōmskōps) ...	3	10	0

Unless otherwise ordered, we adopt the color screens for Lumiere Panchromatic Plates, because the exposures for red and green are both short, and

	£	s.	d.
nearly alike, with these plates. We prefer the quality of negative obtained on another plate, which has a longer scale of correct gradation, but is comparatively insensitive to red, necessitating long exposures for the red image.]			
Extra Dark Slides for small Multiple Back, each ...	0	8	6
Printing Frames, each	0	3	6
Lumiere Panchromatic Dry Plates (8 by 2½), per dozen	0	3	6
Cadett Photomechanical Plates, for Positives (8 by 2½), per dozen	0	2	6
Larger Multiple Back, with Color Screens and one Double Dark Slide making three pictures of ordinary lantern slide size, and correctly centered for the Lantern Krōmskōp	4	10	0
Extra Dark Slides for larger Multiple Back, each ...	0	10	6
Printing Frames, each	0	4	0
Lumiere Panchromatic Dry Plates (9 by 3) per doz.	0	3	8
Cadett Photomechanical Plates, for Positives (9 by 3), per dozen	0	3	0
Superior Front Focussing Quarter Plate Camera, suitable for taking the smaller Multiple Back, with one Quarter Plate Double Dark Slide and Tripod (no extra charge for fitting the Multiple Back to this Camera).	1	17	6
Superior Front Focussing Half Plate Camera, suitable for taking either size of Multiple Back, with one Half Plate Double Dark Slide and Tripod			

	£	s.	d.
(no extra charge for fitting Multiple Back to this Camera)	2	12	6
Extra Quality Front Focussing Half Plate Camera, with one Half Plate Double Dark Slide (no extra charge for fitting Multiple Back to this Camera)	3	3	0
[Photographic Lenses for the above Cameras can be selected from those advertised at the back of this book, all being suitable for this purpose. We supply these or any other lenses at maker's prices.]			
Krōmskōp Cabinet as shown on page 22, substantially made in mahogany and handsomely finished ...	3	15	0
Junior Krōmskōp Cabinet, same make and finish as the above	3	0	0
Ives' and Newton's Universal Science Lantern with Lantern Slide Front, Microscopic Attachment, and Spectroscope Front, and adapted for Krōmskōp Lantern Attachment, without alteration ...	18	0	0
Color Screens for Orthochromatic Photography (permanent sealed screens, superior to colored glasses), $2\frac{1}{4}$ by 2 ins. square	0	2	6
" $3\frac{1}{8}$ by $2\frac{7}{8}$ "	0	3	6
" $3\frac{1}{4}$ by $3\frac{1}{4}$ "	0	4	0
" 4 by 4 "	0	5	0

[For ordinary Orthochromatic Photography we recommend Crysophenine (light lemon yellow), Brilliant Yellow (deeper than Crysophenine), and

	£	s.	d,
Aurantia (orange yellow), all of which, when sufficiently deep, absorb the ultra-violet rays, and improve the rendering even with ordinary plates. For Photo-micrography we recommend deep Napthol Yellow, or Napthol Yellow and Uranine, according to character of sensitive plate and correction of objective.]			
Special Monochromatic Green Secreen $2\frac{1}{4}$ by 2 ...	0	3	6
" " " 3 by $2\frac{1}{2}$ ...	0	4	6
" " " $3\frac{1}{4}$ by $3\frac{1}{4}$ ...	0	6	0
Set of Screens for Color Projection Experiments with ordinary Tri-unial Lanterns, pure red, green and blue- violet, $3\frac{1}{4}$ by $3\frac{1}{4}$ ins. ...	0	12	0
[The separate lights must be so regulated as to make the mixture of the three colors appear white.]			
Set of three ordinary size Lantern Slides constituting a Krōmskōp Color Record...	0	10	0
Metol Cartridges, specially made (without bromide) for developer for Krōmskōp negatives, box of six, each making seven ounces of developer, per box	0	3	6
Xylonite Developing Trays, per pair...	0	2	6

The Photochromoscope Syndicate, Limited,

121, Shaftesbury Avenue,

London, W.C

SHORT HISTORY

VOIGTLÄNDER & SOHN.

THE firm was founded in 1756 by Christoph Voigtländer. In 1811 his son, Friedrich Voigtländer, constructed the first binocular field glasses. The third owner of the firm, Friedrich Voigtländer carefully studied Frauenhofer's methods of examining glasses used for optical purposes and, with a spectrometer, made by himself, obtained the optical data of all the kinds of glass then manufactured. He made use of this with the greatest success, as it enabled him to tabulate practical data for the calculation of optical instruments. He handed these data to the Mathematician, Professor Petzval, of Vienna, asking him to calculate a photographic double objective. According to the calculations Professor Petzval supplied, Friedrich Voigtländer brought out, in 1839, the first photographic doublet, the well-known Petzval Portrait Lens. These Lenses, owing to their rapidity, first enabled satisfactory photographs to be taken of living objects. They were so different from any Optical system previously constructed, that they became the basis of an entirely new class of optical instruments.

The fourth and present owner of the firm, Friedrich Ritter von Voigtländer, constructed, in 1887, the first Euryscope Lenses, which gave a large flat field with much more light than previously obtainable. These Lenses having become rapidly popular various successive series were constructed. The advantages of symmetrical Lenses suggested also improvement in portrait Lenses, and, in 1883, the long focus portrait Lenses were replaced by symmetrical Portrait Euryscopes, Series II. & III.

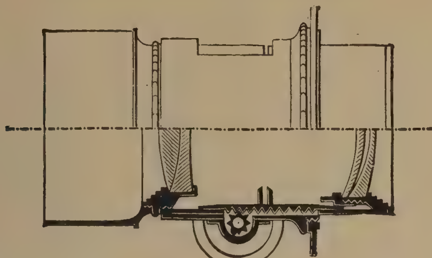
Until recently very few kinds of glass were available for optical purposes, but, in 1886, the Glass Technical Laboratory, of Professor Abbe and Dr. Schott, in Jena, brought out a number of new glasses which influenced the optical industry in a similar manner though to a much greater extent than Frauenhofer's seven glass-fusions. Voigtländer and Sohn were the first opticians to make use of this extension of Optical means as regards Photographic Lenses, and, in 1888, they improved all their symmetrical Lenses, which, until then, had contained two flint glasses and replaced the latter by two extremely transparent crown glasses. The Wide Angle Euryscopes and single Landscape Lenses were entirely reconstructed.

The Collinear Lenses, introduced in 1894, were in 1896, almost reconstructed, with the result that they now combine a larger aperture and covering power with freedom from astigmatism. They are made in three Series with apertures, F5·6, F7·7 and F11·3.

In the 142 years of its existence the business has steadily increased. The latest methods of manufacture and the best modern machinery are used. The works in Brunswick were rebuilt in 1893 and are complete in every respect with steam-power, and own Electric Light Installation. The workshops are large and well heated and ventilated. No apprentices are kept and all the work is done by experienced men who receive pensions amounting to from half to two-thirds wages after being with the firm a certain time. There is a large Studio (over 100 square yards), with dark room, for testing Photographic Lenses, and a long, well-lighted room (over 120 square yards), for testing Field-glasses, Telescopes, etc.

In our works, all, except the smallest Lenses, are polished by hand with the greatest care, thus avoiding undue heating of the glass during this process.

PORTRAIT LENSES.



SERIES I. Full Aperture F3·16.

Extremely Rapid, Petzval form improved with Jena glass.

No.	Equivalent Focus. mm.	inches.	Suitable for	Standard Size Plates	Diameter of Light Circle.	Price.	
3	174	6¾	C.d.v. Bust	5×4	7	£6 0 0	With Rack & Pinion.
4	209	8¼	" "	6½×4½	9	9 0 0	
5	245	9½	Full Lgth. & Busts	8×5	11	13 0 0	
6	306	12	Cabinet	8½×6½	13	18 0 0	Without Rack and Pinion.
7	395	15½	Boudoir	10×8	16½	24 0 0	

SERIES II. Full Aperture F4.

Symmetrical form giving brilliant sharply defined image.

No.	Equivalent Focus mm.	inches.	Suitable for	Standard Size Plates.	Diameter of Light Circle.	Price.	
3	202	8	C.d.v.	6½×4¾	8¼	£6 10 0	With Rack and Pinion
4	263	10¾	"	8×5	11	9 10 0	
5	309	12¼	Cabinets.	8½×6½	13	13 0 0	
6	378	15	"	10×8	15	18 0 0	Without Rack and Pinion.
7	470	18½	Boudoir or Imperial	12×10	11½	24 0 0	

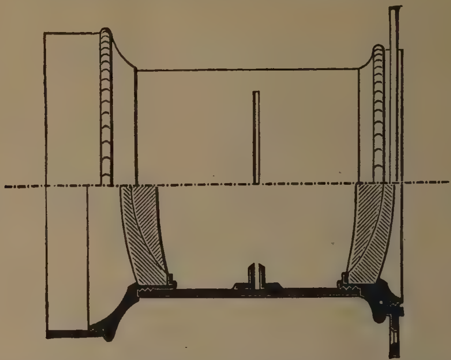
SERIES III. Full Aperture F4½. Angle of View 56°.

These Instruments give a larger field of view and greater depth of definition than any other Portrait Lenses. They are rapid, and being symmetrically constructed, the definition is sharp and image brilliant, owing to the smaller number of reflecting surfaces.

No.	Equivalent Focus mm.	inches.	Suitable for Plates	Diameter of Light Circle.	Price. Without Rack & Pinion.	With Rack & Pinion.
1	163	6½	5×4	7	£4 10 0	£5 10 0
2	198	7¾	6½×4¾	8½	5 10 0	6 10 0
3	217	8½	7½×5	9½	7 10 0	8 0 0
4	286	11¼	8½×6½	12	10 0 0	11 0 0
5	344	13½	8½×6½ or 10×8	15	14 0 0	16 0 0
6	412	16¼	10×8 or 12×10	16½	20 0 0	—
7	514	20¼	15×12	20	26 0 0	—
8	658	26	18×16	25½	47 10 0	—

EURYSCOPE LENSES

SERIES IV.



Full Aperture F6·3.

Angle of View. 70°.

These Instruments, owing to their relatively extensive field of view, combined with depth of definition and rapidity, have been extensively used for almost every class of Photographic work.

Very good portraits and groups can be taken in the Studio, specially with the larger sizes, and for this purpose they can be used with full aperture. Their rapidity is so great that very short exposures can be given for outdoor and Hand Camera work. They are also efficient for landscapes and general objects.

No.	Equivalent Focus.		Suitable for Plates.	Diameter of Circular Image.	Price. Waterhouse. Diaphragms.			Iris.		
	mm.	inches.	inches.	inches.	£	s.	d.	£	s.	d.
0	127	5	4¼×3¼	8	3	0	0	3	10	0
00	174	6¾	6½×4¾	10½	4	0	0	4	10	0
1	216	8½	7½×5	12½	5	0	0	5	12	0
2	254	10	8½×6½	15	5	16	0	6	8	0
3	291	11½	8½×6½ or 10×8	16½	7	0	0	7	12	0
4	382	15	10×8	20	10	0	0	10	12	0
5	448	17½	12×10	24½	15	0	0	16	0	0
6	547	21½	15×12	29	20	0	0		—	
7	655	25¾	18×16	34½	26	0	0		—	
8	852	33½	24×18	44	47	10	0		—	
9	1070	42¼	27×23	53	112	0	0		—	

MEDIUM RAPID EURYSCOPE. Series VI.

Full Aperture F7·7. Angle of View 78°.

These Lenses though rapid have not so large an aperture as the preceding ones but exceed them in depth of definition and angle of view. They are among the best all round Lenses and will be found most useful for Groups, Landscapes, Copying and Architectural Work. The back Lens can be used alone as a single Lens of about double the focal length of the combination.

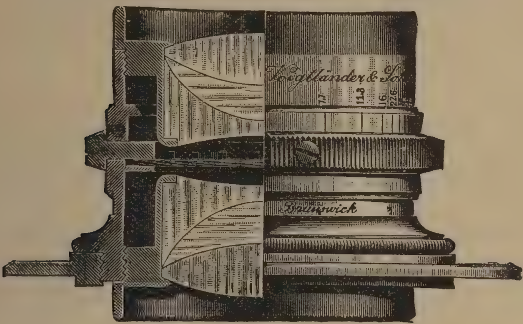
No.	Equivalent Focus.		Suitable for Plates.	Diameter of Circular Image.	Price. Waterhouse. Diaphragms.			Iris.		
	mm.	inches.	inches.	inches.	£	s.	d.	£	s.	d.
x	145	5¾	4¼×3¼ or 5×4	11	3	0	0	3	10	0
0	178	7	6½×4¾ or 7½×5	13	3	8	0	3	18	0
00	240	9½	7½×5 or 8½×6½	16	4	4	0	4	14	0
1	295	11½	9×7	19	5	12	0	6	4	0
2	358	14	10×8	22	6	12	0	7	4	0
3	421	16½	12×10	25	8	0	0	8	12	0
4	500	19¾	15×12	28	12	0	0	12	12	0
5	609	24	18×16	34	17	12	0	18	12	0
6	724	28½	24×18	40	23	0	0		—	
7	869	34	27×23	47	30	0	0		—	
8	1080	42½	31×27	59	55	0	0		—	

New Series.

COLLINEAR LENSES.

These Lenses have been recently remarkably improved, and are now much more efficient than the original series. They consist of symmetrical back and front combinations, each of which consists of three lenses cemented together; they can also be supplied non-symmetrical. They give an anastigmatic, sharp and flat field, with a wide angle and great rapidity. The results are remarkable, as the image is almost geometrically exact; for this reason the name Collinear has been given to them. The ratio of Diaphrams to each other is according to the Standards fixed by the Royal Photographic Society.

COLLINEAR LENSES. Series II.



Full Aperture. F5·6.

These Lenses are extremely suitable for Hand Cameras, Instantaneous Pictures, Animals, Studio Work, especially Groups in the Studio.

No.	Equivalent Focus.		Sizes of Plates Sharply Covered.			Price, with Iris.		
			F6·3.	F8.	F32.			
	mm.	inches.	inches.	inches.	inches.	£	s.	d.
1	90	3½	3¼ × 3¼	4 × 3	4¼ × 3¼	4	16	0
2	120	4¾	4¼ × 3¼	6½ × 4¾	7 × 5	5	12	0
3	150	5⅞	6¾ × 4¾	7½ × 5	8½ × 6½	6	8	0
4	200	7⅞	7 × 5½	8 × 6	10 × 8	8	12	0

Full Aperture F6·3.

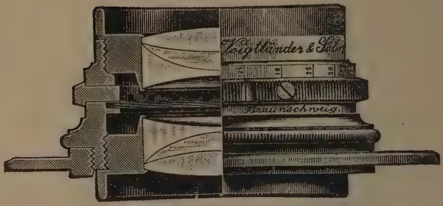
Suitable for Instantaneous Photographs and Portraits and Groups in the Studio or out of Doors, Large Heads and all round work.

No.	Equivalent Focus.		Sizes of Plates Sharply Covered.			Price, with Iris.		
			F6·3.	F8.	F32.			
	mm.	inches.	inches.	inches.	inches.	£	s.	d.
5	250	9⅞	8 × 6	8½ × 6½	10 × 8	11	0	0
6	300	11⅞	8½ × 6½	9 × 7	12 × 10	15	0	0
7	370	14½	9 × 7	10 × 8	15 × 12	20	0	0
8	430	17	10 × 8	12 × 10	18 × 16	27	0	0
9	510	20	11½ × 9½	15 × 12	24 × 18	34	0	0
10	600	23⅝	15 × 12	18 × 16	27 × 23	45	0	0

COLLINEAR LENSES.

WIDE ANGLE TYPE.

SERIES



IV.

Full Aperture, Nos. 1 to 5, F11·3.

Full Aperture, Nos. 6 to 10, F12·5.

For Reproductions, Copying, Architecture, Interiors, etc., this is the first series of Symmetrical Anastigmat Wide Angle Lenses made in small as well as large sizes. With full Aperture a field of 75° is perfectly sharp, and with smaller stops up to over 90°, and in this large field no trace of astigmatism or unevenness can be found. The following sizes of plates, as in the case of Series II., III., are by no means the maximum. In most cases much larger plates will be covered sharply. If a too short focus lens is used, the perspective is not so good. The definition obtainable is extremely sharp.

No.	Equivalent Focus.		Size of plate sharply covered.			Price with Iris.		
			F11 3.	F32	F64.			
	mm.	approx. inches.	ins.	ins.	ins.	£	s.	d.
1	100	4	4¼ × 3¾	6 × 4	6½ × 4¾	4	0	0
2	120	4¾	6 × 4	7 × 5	7½ × 5½	5	0	0
3	150	6	7½ × 5	8 × 6	9 × 7	5	0	0
4	200	8	9 × 7	11 × 9	12 × 10	6	0	0
5	260	10¼	11 × 9	12 × 10	15 × 12	9	0	0
			F12·5.					
6	320	12⅝	12 × 10	15 × 12	17 × 12¼	12	0	0
7	440	17½	15 × 12	18 × 16	22 × 18	20	0	0
8	600	23½	18 × 16	24 × 18	23 × 19	30	0	0
9	800	31½	24 × 18	27 × 23	27 × 27	45	0	0
10	1000	39½	27 × 23	31 × 27	35 × 31	63	0	0

NON-SYMMETRICAL LENSES.

We can supply our Collinear Lenses with front and back lens of different foci, thus combining in one instrument two single lenses and one doublet, working at from F7·2 upwards. We would specially state that these combinations are thoroughly efficient instruments. They are much more portable, and take up less room than three separate lenses. We should be glad to quote for these non-symmetrical lenses.

We can specially recommend combinations formed of Collinear Series IV., and give the following as an example. The single lens when used on plates suitable for the doublets show scarcely any distortion, and can be used for Architectural work; for instance, no distortion can be seen over 10 × 8 plate with 16 in. focus single lens of this series.

COLLINEAR SERIES IV.

	Largest Diaphragm F.	Size of Plate sharply covered.		Price.
		Full Aperture.	Small Stops.	
			inches.	£ s. d.
Single Lens, 10¼ inches focus	22·6	12 × 10 in.		
" " 13¾ " "	32·6	15 × 12 "		5 10 0
Combination 6¾ " "	12·5	8 × 6 "	12 × 10	

The utmost definition is obtainable with the above.

CINEMATOGRAPH LENSES.

We have constructed specially small lenses on the same formula as our Collinear Lenses, Series II. and III., also Portrait Lenses, Series I., which have been used with great success for Cinematograph Cameras and Lanterns.

These small Collinears have a large flat field with perfect definition. They are not suitable for projection purposes, for which our Portrait Lenses are very efficient and pass the maximum amount of light.

Prices of Collinear Lenses for CINEMATOGRAPH CAMERAS.

	Full Aperture.	No.	Focus.	Price.		
			inches.	£	s.	d.
*Collinear Lens, Series II	F5·4	0	2¼	3	12	0
" " " II.	F5·4	1	3½	4	16	0
" " " III.	F7·7	0	2⅛	2	14	0
" " " I·I.	F7·7	00	2¾	3	14	0

* We recommend this Lens as being the most useful one.

Prices of Projection Lenses for CINEMATOGRAPH LANTERNS.

	Full Aperture.	No.	Focus.	Price.		
			inches.	£	s.	d.
Portrait Lens, Series I. ...	F3·16	0	2¾	3	4	0
" " " " ...	"	1	4	4	0	0

Telephotographic Attachments, Series I.

These enable pictures to be obtained on from three to twelve times as large a scale as can be obtained with the lens they are fitted to. The magnification depends on the bellows extension available These attachments give very sharp definition and brilliant images, as the negative lens is a threefold cemented one.

PRICES.

Telephoto Attachment	suitable for	5 to 6 ins.	focus Lens	£4	0	0
,,	,,	,,	7 to 8 ins.	,,	4	15	0
,,	,,	,,	10 ins.	,,	5	10	0
,,	,,	,,	12 ins.	,,	6	10	0
,,	,,	,,	15 ins.	,,	8	0	0
,,	,,	,,	17 ins.	,,	10	0	0

Telephotographic Lenses, Series II.

Extra rapid, for Instantaneous Work and Portraiture. Full particulars on application.

Wide Angle Landscape Lenses.

Angle of View, 80°. See Complete Catalogue.

Extra Rapid Lenses, for Astronomical Photography. Full Aperture F2.

Extreme Rapidity, with very sharp definition and a flat field.

Collinear Lenses, Series III. Full Aperture F7·7.

See Complete Catalogue.

VOIGTLÄNDER & SOHN are the inventors of Binocular Field and Opera Glasses which they first made in 1811.

A Field Glass or small Telescope is a most useful addition to a Photographic outfit, specially when travelling. We recommend the following instruments, all of which are made with the same care and precision as our Photographic Lenses.

Field Glasses, Series J. Bodies covered best Morocco, all metal parts bronzed dull black. Achromatic Eye-pieces and Object Glasses.

Field Glasses, Series K. The same as above but mounted in Aluminium.

Porro Binocular Field Glasses. Two sizes, six and eight times magnification.

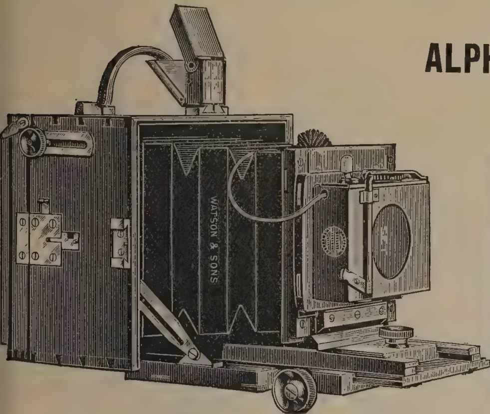
Binocular Telescopes. With two magnifications.

Terrestrial Telescopes. Specially useful when Telephoto Lenses are used, Double or Triple Object Glasses. The latter should be selected if the best possible correction for the secondary spectrum is required.

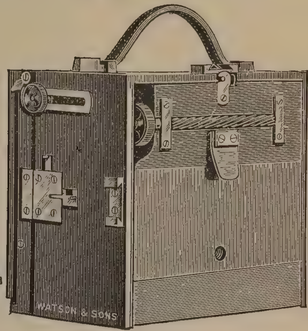
Our Photographic Lenses, Field Glasses, Telescopes, etc., can be obtained through all Dealers and Opticians.

W. WATSON & SONS' PHOTOGRAPHIC APPARATUS

WATSON'S
ALPHA HAND CAMERA.



OPEN.



CLOSED.

This Camera combines every movement requisite for use either in the Hand or on a Tripod. As will be seen by the illustrations the Lens and Shutter are always in position and close inside the body of the Camera, which is very compact and light.

COMPLETE OUTFITS.

	ENGLISH.			CONTINENTAL.	
SIZES	¼-plate.	5×4	6½×4¾	9×12 c/m	13×18
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Camera with Double Action Front, Double Extending Base, Swing Back and Rack-work Focussing Adjustment, and three Double Dark Slides	6 10 6	7 1 6	8 5 6	7 1 6	8 15 6
Rapid Rectilinear Lens, with Iris Diaphragm	2 17 6	3 2 6	4 0 0	3 2 6	4 10 0
Exposure Shutter	1 0 0	1 0 0	1 0 0	1 0 0	1 0 0
Finder	0 10 6	0 10 6	0 10 6	0 10 6	0 10 6
Best Solid Leather Travelling Case, with Lock and Key	1 2 0	1 5 0	1 10 0	1 5 0	1 10 6
	12 0 6	12 19 6	15 6 0	12 19 6	16 6 0
Extra if Camera and Slides are Brass Bound for Hot Climates	1 2 0	1 5 0	1 10 0	1 5 0	1 10 0
Extra for Leather Covered Body and Bronzed Mounts	0 12 6	0 15 0	0 18 0	0 15 0	0 18 0
Aluminium instead of Brass Mounts ..	0 13 6	1 1 0	1 3 6	1 1 0	1 5 6
Aluminium Binding in similar manner to Brass Binding — supplied only to Aluminium Mounted Cameras	1 2 0	1 5 0	1 10 0	1 5 0	1 10 0

The above prices are subject to 5 per cent. Discount for Cash with Order.

These Cameras can have fitted to them Ives' New Multiple Dark Slide, taking Triple Negatives for the production of Transparencies, showing objects in natural colors.

W. WATSON & SONS, 313, HIGH HOLBORN, LONDON.

LOMAS OF HONOUR
ND PRIZE MEDALS.
LONDON,
1851, 1862, & 1885.

SILVER MEDAL,
ENTRAL INDIA, 1868.
PARIS, 1878.
HIGHEST AWARD,
BRAZIL, 1884.

NEWTON & Co.,

Opticians, Scientific Instrument,

AND GLOBE MAKERS,

TO H.M. THE QUEEN, HIS LATE R.H. THE PRINCE CONSORT,
H.R.H. THE PRINCE OF WALES,
THE ADMIRALTY, WAR DEPARTMENT, H.M. TRAINING SHIPS,
THE INDIAN AND FOREIGN GOVERNMENTS,
SCIENCE AND ART DEPARTMENT ETC.

By Special Appointment
TO THE ROYAL INSTITUTION OF GREAT BRITAIN.

3, Fleet Street, Temple Bar, London.

ROYAL AGRI: SOCIETY
SILVER MEDAL, 1893.

BY SPECIAL
APPOINTMENT.

THE "UNIVERSAL" SCIENCE LANTERN.

(IVES AND NEWTON'S PATENT.)

This Lantern has been devised with a view to producing an instrument which shall be extremely portable and which shall yet be capable of producing, with a minimum of trouble and rearrangement, most of the experiments required by Science Lecturers.

The Lantern is fitted with 3 fronts, any one of which can be exchanged for any other, in one second of time.

The first front is for shewing ordinary slides and diagrams and comprises 4 in. condenser and 6 in. best double achromatic front lens, exhibiting slides as well and clearly as any lantern we can make.

The second front is a microscopic attachment fitted with sub-stage condenser and low power objective. Any additional higher powers can be supplied, and polarizing prisms fitted if required.

The third front is for spectroscopic work and is fitted with slit, direct-vision prism and achromatic focussing lens, which project a brilliant spectrum on the screen without the necessity of placing the lantern at an angle.

A comparison prism is also fitted, by which, at the same time, an image is projected on the screen of any solution or coloured glass or gelatine of which the absorption spectrum is being shewn.

These 3 fronts can be removed and a Photochromoscope or a Vertical Attachment or an Elbow Polariscope or a Cinematograph or any other front substituted in 5 seconds.

The condenser is mounted on a hinge and can be removed or put in position instantly. Either lime-light or the electric arc can be used in this Lantern and as it is made throughout in Messrs. Newton and Co.'s workshops it is perhaps unnecessary to say that every detail has been carefully arranged and that the workmanship is of a very high class.

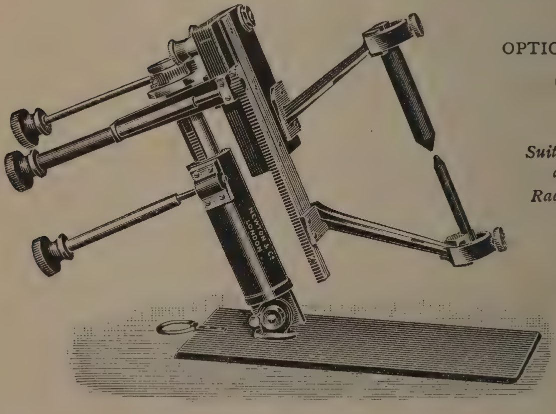
	£	s.	d.
Price of Lantern with lantern-slide front, microscopic attachment, and spectroscope front, and fitted to take instantly any of the additional fronts mentioned above without alteration	18	0	0
Photochromoscope for projecting Ives' 3 colour system of colour photography with 6 sets of slides	10	10	0
Vertical Attachment with lenses, prism, &c.	5	5	0
The "**English**" **Cinematograph** fitted to above	18	0	0
Elbow Polariscope fitted to above	8	8	0
Polarising Prisms fitted to Microscopic Attachment			
Double Sliding Carrier for lantern slides	0	3	0
Higher Power Objectives for the Microscopic Attachment:			
$1\frac{1}{2}$ in.	2	5	0
$\frac{8}{10}$ in.	2	7	6
$\frac{4}{10}$ in.	1	10	0
Portable Cabinet Case to contain Lantern and 3 fronts, capable of being carried in the hand	0	17	6

This "Universal" Lantern is described and figured on pages 27-28 of this book.

SOLE MAKERS:

NEWTON & CO., 3, Fleet Street, London.

The "UNIVERSAL" ELECTRIC ARC LAMP.



FOR
OPTICAL LANTERNS.

(HAND-FEED.)

(PATENT.)

Suitable for both direct and alternating currents.

Rack adjustments in every direction.

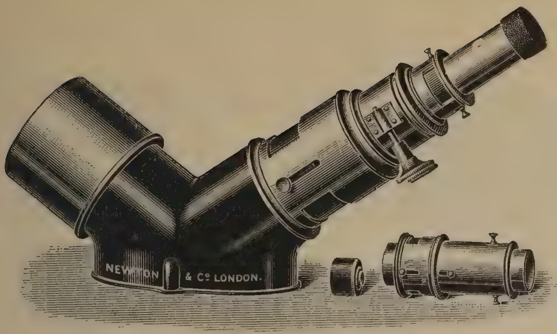
Sole Makers:

Newton & Co.,

3, *Fleet Street,*

London.

Price £4 4s.

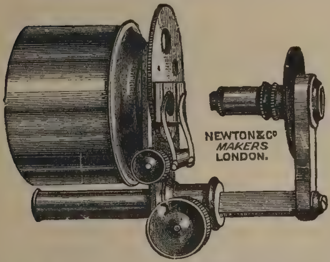


LANTERN POLARISCOPES

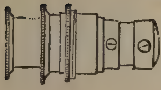
AND APPARATUS FOR USE WITH OPTICAL LANTERNS.

	£ s. d.
Elbow Polariscope, of best quality and construction, for illustrating the various phenomena of polarized light, with polarizing glass plates, prism and lenses, mounted in brass, with rack adjustment to focus tube, in case, complete ...	7 7 0

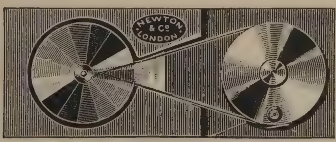
This instrument is suitable for use with any good Optical or Magic Lantern, and forms an excellent Table Polariscope.



Newton's Patent Microscopic Attachment, adjusting sub-stage condenser and special double achromatic objective, complete ...	4 14 6
Microscopic Attachment. Cheaper form, with objective as above ...	3 10 0



Kaleidoscope, for giving an endless variety of patterns and very beautiful effects with the chromatrope, mounted in brass to attach to the front of any Lantern, in case ...	2 10 0
Rackwork Slide, with pieces of coloured glass for the Kaleidoscope ...	0 7 6



White Light Slide for showing the composition of white light on the screen	0 12 6

£ s. d.

Wright's Wave Slide for showing the motion of light waves and retardation of wave vibrations, on the screen 0 15 0

Dorman's Sound Wave Slide for showing the motions of particles in a sound wave; four lines of wave motion are shown travelling outwards at right angles to each other as from a bell 0 8 6

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Anorthoscope Slide. This slide exhibits on the screen the same effect as the table anorthoscope, five symmetrical images produced from one distorted image by means of a rotating disc with four slits, with adjustment and jockey wheel for keeping bands taut 1 7 6

Extra Designs for the above, 8 different, each 0 2 6

Gorham Colour Top Slide, giving various colouring to a design which is multiplied by a slotted rotating disc, the colours changing on the screen, with adjustment and jockey wheel for keeping the bands taut 1 7 6

Extra Designs for the above, 5 different, each 0 2 6

Cheshire's Sound Wave Disc Slide 0 18 6

This slide, invented by Mr. Frederic J. Cheshire, of the Birkbeck Institution, London, and described in *Nature* for 1892, shows the mode of vibration of the particles in stationary wave systems such as those occurring in organ pipes, rods vibrating longitudinally, &c. By using different lengths of the slit the way in which the vibrating column divides up into nodes and loops when the different overtones are being produced is illustrated. The vibrations in a closed organ pipe, in an open organ pipe, the first overtone in closed and open pipes, the vibration of a rod clamped at one end, at both ends, and in the middle can all be readily shown.

Benham's Top Slide 0 10 6

This slide has been designed to show on the screen the curious colour effects described by Mr. Benham, of Colchester. Black lines on a white disc when rotated appear red, yellow, green, and blue, according to their relative positions, though each one is the same proportion of its own circle, *i.e.*, one-eighth. On reversing the rotation the colours are all reversed. This should be shown by lime or electric light on a *small* disc; it is then very effective.

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